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FOREST SERVICE RESEARCH ACCOMPLISHMENTS

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ACKNOWLEDGEMENT

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
P. O. Box 2417
Washington, D.C. 20013

1380 (4000)

Honorable M. Rupert Cutler
Assistant Secretary
U.S. Department of Agriculture
Washington, D.C. 20250

Dear Dr. Cutler:

I am pleased to send you the report on Forest Service Research Accomplishments for 1976.

This report summarizes Forest Service research achievements and lists research publications. It reflects the emphasis of a research program directed at solving the multifaceted problems of managing our Nation's renewable natural resources.

New knowledge and technology reported here will be useful to other scientists and to practitioners in Federal, State, and private employment. The Forest Service is strengthening its efforts to assure that this information is quickly transferred to and utilized by those who need it.

Sincerely,

John R. McGuire

JOHN R. McGUIRE
Chief

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U.S. DEPARTMENT OF AGRICULTURE

NOTICE: The identification and description of commercial products in this publication are solely for information purposes. Endorsement of any commercial product is not intended and must not be inferred. Readers are cautioned to handle all pesticides, herbicides, and fungicides mentioned in this publication strictly in accordance with manufacturer's labels. These chemicals are harmful to people, farm animals, wildlife, and fish, and can contaminate water supplies.

FOREWORD

Forest Service research plans are coordinated through the Assistant Secretary for Conservation, Research, and Education with research in other USDA agencies, as well as that conducted under the Hatch Act at land grant institutions, and under the McIntire-Stennis Act at schools of forestry.

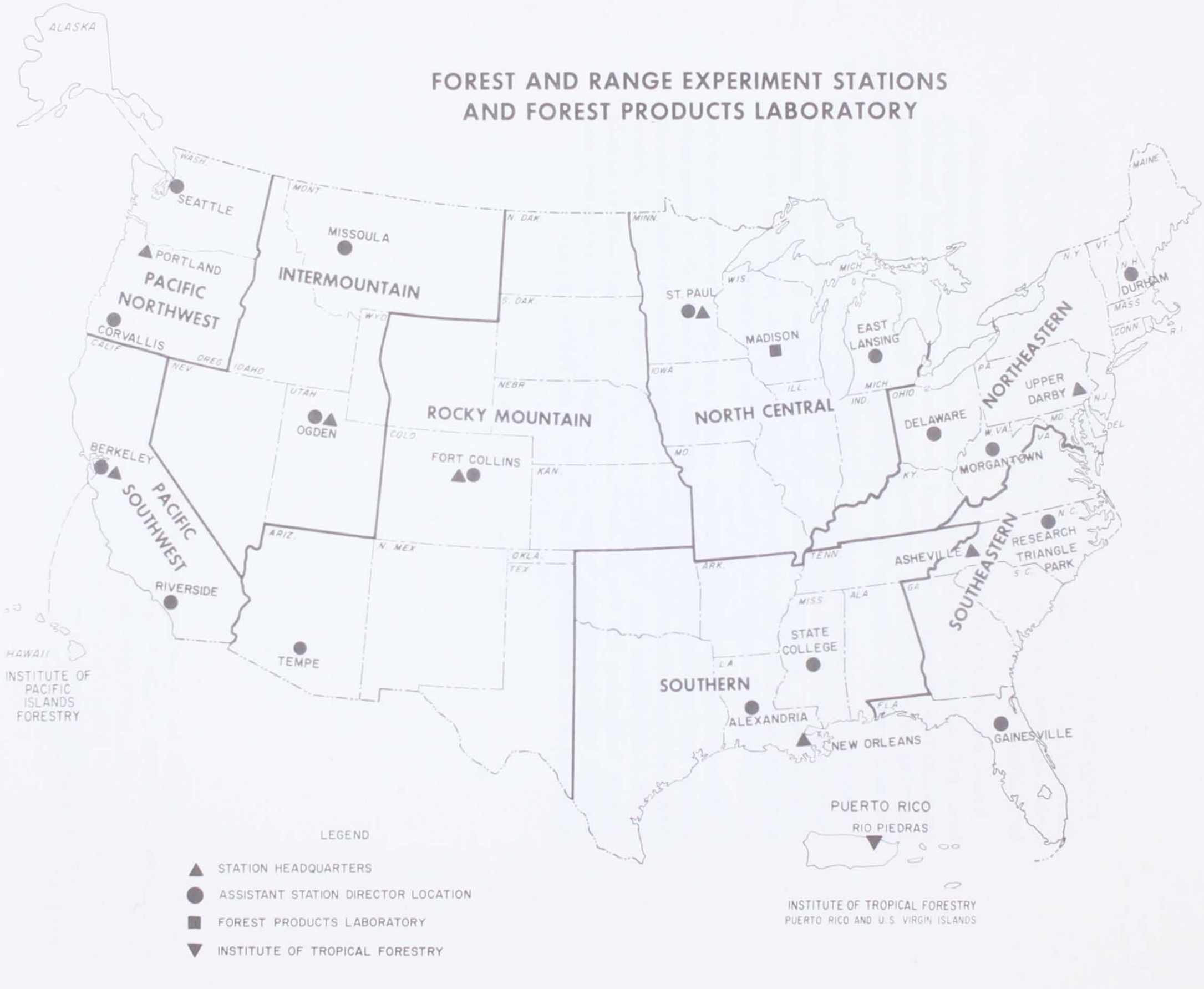
Development and coordination of research with other educational institutions, private enterprises, nonprofit institutions, and other public agencies are accomplished through the Regional and National Agricultural Research Planning Program directed by the Agricultural Research Policy Advisory Committee and the National Planning Committee.

Coordination is also maintained through direct contact between people of these organizations and those of the Forest and Range Experiment Stations. Federal, State, industry, and university cooperation in solving mutual problems is achieved through cooperative agreements providing for joint development and support of the research by the cooperators.

This report is arranged by research subject areas as a convenience to the reader. Each accomplishment is summarized in a single, short paragraph. Numbers in parentheses following the paragraph indicate relevant documents in the Publications List. Following each publication citation is an abbreviation indicating the Forest Service research unit best able to supply detailed information and copies of the publication. Abbreviations and addresses of the research units are given on the following page.

Issued May 1977

FOREST AND RANGE EXPERIMENT STATIONS AND FOREST PRODUCTS LABORATORY



LEGEND

- ▲ STATION HEADQUARTERS
- ● ASSISTANT STATION DIRECTOR LOCATION
- ■ FOREST PRODUCTS LABORATORY
- ▼ INSTITUTE OF TROPICAL FORESTRY

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INT
Director
Intermountain Forest and Range Experiment Station
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Ogden, Utah 84401

RM
Director
Rocky Mountain Forest and Range Experiment Station
240 West Prospect Street
Fort Collins, Colorado 80521

NC
Director
North Central Forest Experiment Station
Folwell Avenue
St. Paul, Minnesota 55101

NE
Director
Northeastern Forest Experiment Station
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Upper Darby, Pennsylvania 19082

SE
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Southeastern Forest Experiment Station
Post Office Building, P. O. Box 2570
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Southern Forest Experiment Station
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ITF
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IMPROVING ENVIRONMENTAL QUALITY, PRODUCTIVITY, AND USEFULNESS

REDUCING POLLUTION

Controlling soil erosion

1. Erosion following wildfire on either unlogged or cutover areas is an important concern to land managers especially in areas of highly erodible soils such as the Idaho Batholith. A variety of post-wildfire measurements of erosion, vegetation responses, and soil and water repellancy was conducted on a clearcut and an undisturbed watershed. Fuel loading was much higher on the clearcut watershed. This resulted in a greater burn intensity and considerable erosion on the clearcut drainage. The undisturbed watershed exhibited only slight erosion due to protection offered by dead, standing trees, unburned litter, and more rapid vegetation regrowth. This information reinforces the need for proper slash disposal on logged areas. (13)

2. The role of sediment storage in channels, previously overlooked, was studied in channels draining seven small undisturbed forested watersheds in central Idaho. The annual change in sediment stored was measured. Additional data were collected to evaluate the influence of natural obstructions on sediment storage. Extremely large volumes of sediment were trapped behind obstructions in two sample years; only about 10 percent of the stored sediment appeared as annual sediment yield. A continuity equation was used to estimate the annual watershed erosion. This study illustrates the need to include channel sediment storage as a subsystem in predictive modeling of sediment. (14)

3. Resource planners need to evaluate the impact of possible reduced water quality from areas subject to forestry activities. The hydrologic potentials of sub-units of a watershed for producing water, floods, and sediment, were evaluated with models that characterize potential impacts of proposed land uses. The techniques illustrated suggest ways for the planners to obtain quantitative evaluations of sedimentation and water quality hazards in land units being considered for specific uses. (1,2,3,4,5)

4. Water movement in coarse textured soils on burned chaparral areas in southern California is impeded by hydrophobic substances coating the mineral soil particles. Lower infiltration rates in these water repellent soils are important factors when evaluating runoff and erosion from brushland areas. The relationships presented provide a fundamental basis for understanding how water moves through these soils and show, contrary to common experiences with soils, that infiltration is slowest in a dry soil and increases as soil water increases. Slower infiltration resulting from repellency may not be desirable for erosion control purposes. However, water repellency also decreases evaporation which may provide a water saving mechanism useful for plants living in the arid southwest environment. (6)

5. Prescribed burning is being considered as a possible tool for widespread fuel modification on chaparral areas in southern California. The impact of fire on plant nutrients is an important consideration when initiating a large scale burning program. A recent study showed that less than 6 percent of the total nutrients found in the upper soil layers was lost immediately after a fire. Results of this experiment should be useful for estimating nutrient losses from chaparral brushland areas, having slopes of 50 percent or less, after a prescribed burn in the summer. (65)

6. Forest management can significantly affect slope stability in the western Cascades. Studies show that the present landscape of the H. J. Andrews Experimental Forest was formed during the past 4 million years by alluvial, glacial, and mass movement processes. The occurrence of both deep-seated and shallow mass movements is controlled by bedrock geology. Identification of this close link between bedrock geology and mass movement is useful in forest management decisions such as road planning on similar lands in the western Cascades. (16)

7. Bare roadside slopes are especially vulnerable to erosion during the first few months after construction. Despite successful germination and early establishment, legumes are unable to compete with grasses and largely disappear from most roadside stands after 1 year. In western Oregon, grass-legume seed, fertilizer, and straw mulch applied to road backslopes, for the most part, successfully halted erosion. Infertile subsoils required refertilization. The mulch, fertilizer, and grass-legume mixtures identified in this study provide a good tool for stabilizing road cut and fill slopes. (8)

8. Intensive forestry cultural practices in the Gulf Coastal Plain must be evaluated in terms of their potential impact on soils and on water quality. Results from severely eroded watersheds now stabilized with pine plantations show an average annual sediment content of 58mg/l in stormflow from undisturbed forest conditions, with concentrations sometimes exceeding 140mg/l. A maximum of 80mg/l of suspended solids is suggested by EPA. Pollution regulations must be based on sound data. A research approach to obtain these data is outlined. (11)

9. The hydrologic impact of skidding tree length logs up slopes of erosive Gulf Coastal Plain soils was evaluated over a 2-year period. Stormflow from the skid trails averaged 28.4 cm, while flow from undisturbed areas averaged only 2.8 cm. Soil loss averaged 14.8 kg. per trail in the first year but diminished rapidly as the bared soil became covered by herbaceous vegetation. Results will help land managers decide on measures needed to reduce sediment production. (7)

10. Gathering erosion data can be time consuming. A fast and efficient way of collecting erosion data has been developed. Research scientists at Bera, Ky. have developed a method whereby they photograph a micro-topographic profile gage to produce charts that can be analyzed with a chart reader. Erosion measurements that would normally take days in the field and weeks in the office are now reduced to a matter of hours. (45)

11. Knowledge of land form evolution from youthful to old-age stages is needed to develop criteria for understanding gully

development and control. In a western study, youthful and early mature stages of gully development were defined. Comparison of hydraulic geometry of gullies with that of rivers suggests that mature stages should be characterized by dynamic equilibrium. Gully stages expressed in terms of erosion rates and sediment yields would be useful to watershed managers. (9)

12. Vegetative cover that perpetuates itself without further maintenance is needed to rehabilitate disturbed sites. Two planting sites with narrow submerged burlap strips showed 14 times less soil loss than control sites without burlap. Plant cover is established before disintegration of the burlap, in about 5 years. This method provides land managers with a proven technique for bank stabilization and erosion control. (10)

13. Information on erosion and sedimentation rates, essential for proper land management, is not available for sagebrush lands. Seasonal trends in sediment transport were described for two Wyoming watersheds having perennial waterflow at 2380m elevation. With peak sediment concentration of 300 ppm during maximum flow, and average summer levels of 20 ppm, sediment yields compared favorably with those from subalpine forests. The results can aid in evaluating effects of various management practices on sediment yields. (15)

Chemicals in the forest environment

14. Stream contamination can result from application of herbicides to forest land. A peak concentration of 0.037 mg/l dicamba occurred in water 1.3 kilometers downstream from a 67 hectare treated portion of a 244 hectare watershed in western Oregon. No residues were detected more than 37.5 hours after application. A 25 percent reduction of dicamba in streamwater occurred between sampling stations located 3.1 kilometers apart. Residue levels detected pose no acute toxic hazard to aquatic organisms or to downstream water users. Knowlege of the behavior of chemicals is important to the prevention of environmental contamination. (23)

15. Nitrogen fertilization, an important practice in part of the Douglas-fir region, has a potential for stream contamination. Application of nitrogen fertilizers was monitored in the Douglas-fir region between 1968 and 1974. Direct application of urea to drainage channels was usually responsible for the highest nitrogen concentrations. Maximum concentrations of nitrogen in the streams after fertilization have not exceeded levels acceptable for public water supplies. (21)

16. Urea fertilization of Douglas-fir stands in western Washington can reduce water quality. Applied fertilizer reached surface streams as urea, ammonia, and nitrate-nitrogen but maximum concentrations were well below limits established for public water supplies. The highest level of nitrate-nitrogen was 0.1 mg/kg. The amounts of nitrogen in the forest streams should have little impact on eutrophication. (22)

17. A root pathogen, *Phellinus weirii* (Murr.) Gilb., kills many immature Douglas-fir in the Pacific Northwest. Laboratory cultures were grown with different carbon and nitrogen sources and vitamins to see if the fungus prefers certain nutrients. Significant differences in mycelia weights resulted from different C and N sources. All but one vitamin produced no effect. The study suggests ways to improve media used for studies of *P. weirii* and aids in understanding the role of the fungus in C and N cycling. (19)

18. A greater understanding of pesticide effects on forest ecosystems is needed. A computer model was developed to simulate the movement of 2, 4, 5-T and picloram in an Oregon forest and southern California chapparral. Seasonal changes, the action of chemicals on natural processes, and physical environmental effects were considered. In addition to identifying research needs on the two herbicides, the model provides a means to make accurate predictions of pesticide effects and to specify correct application parameters. (24)

19. Cacodylic acid is widely used as a silvicide and herbicide but might be toxic to cattle. Five cattle were subjected to 10 mg/kg/day for 3 weeks, followed by 20 mg/kg/day for 3 more weeks. Post-mortem examinations indicated damage to the intestines, liver, and kidney. Kidney tube damage and accumulation of arsenic in hair were extensive. The results may be useful in diagnosis of cacodylic acid poisoning. (18)

20. Forest fertilization with nitrogen may affect stream water quality. To shed light on this problem, four streams in southeast Alaska were studied, two in urea fertilized drainage and two in unfertilized drainage. N levels increased for up to 1 year in the treated streams but remained safe for aquatic life and public use. No changes were noted in bottom aquatic organisms. If proper care is used, forest fertilization is an environmentally sound practice. (20)

21. Conversion of chaparral to grass has been shown effective in increasing water yield. Spot treatments and broadcast applications of soil-applied karbutylate show promise as a chemical control for chaparral. Water samples collected at the stream gaging station showed varying concentrations of karbutylate depending on the length of time since treatment. Karbutylate was not detected in samples taken about a half mile downstream from the treated watershed. In view of the low levels of residues resulting from a 20 lb/acre application and because of the low toxicity rating of karbutylate, there is reasonable hope that karbutylate will be an environmentally safe chemical for controlling chaparral. (17)

22. Of major concern when an herbicide is used is how long it persists in the environment. Recent research in central Louisiana indicates that both picloram and dicamba remain in sprayed foliage until the leaves fall. Picloram was more persistent and was influenced less by soil type and litter cover than dicamba. Dicamba was less effective and less persistent on well-drained, Ruston sandy loam with litter cover than on Beauregard clay loam. These results define some factors to be considered in assessing the persistence of picloram and dicamba when applied as a foliar spray and will be of value to other researchers seeking effective, environmentally safe herbicides. (842)

Air Pollution

23. The effects of open burning on ambient air quality are not generally known. About 1 million acres of agricultural and forestry land are burned by prescription in Georgia each year. Since atmospheric conditions ideal for open burning are also ideal for smoke dispersion, overall concentrations of most particulates in rural areas are higher at other times of the year than when most open burning is occurring. Furthermore, a general smoke dispersion model has been developed as a way to incorporate air quality criteria into prescribed burning decisions. It appears that open burning is causing no greater area-wide air pollution problem in Georgia than the sum of other activities at other times.

Managers applying these results can be relatively sure that smoke from their prescribed fires will not become a public hazard. (682,673,686)

24. Particulate emissions are the most objectionable atmospheric contaminant from forest burning, and little is known about particulate sizes. Electron photomicroscopy of particulate emissions from laboratory burning of logging residues confirmed the existence of two basic particle structures—a smooth, spherical, submicron particulate suspected to be condensed tars and a group, polydisperse in size, that did not tend to agglomerate. This basic type of information is needed for the development of smoke management strategies. (720)

25. Assessment of recreational development on air quality is not being done with any specific or approved procedure by the Forest Service. A procedure has been developed which includes use of models coupled with onsite data collection and other information resources. Such a general procedure requires more elaboration, but it eventually should form the basis for Forest Service procedures in air quality analysis. (733)

26. Air pollution decreases the growth of ponderosa pine on the San Bernardino National Forest. Annual stem growth data are needed for management planning in those stands with chronic injury caused by oxidant air pollutants. Average radial growth, based on a 30-year period, was significantly higher in nonpolluted areas than in polluted areas of the forest. This information can be used by land managers to develop stand management prescriptions. (667)

27. Lack of consolidated background material prevents efficient investigation of present and potential effects of air pollutants on forests. A broad literature review has been prepared which contains the histories of important incidents of damage to forests in the United States and Canada caused by the most serious pollutants—sulfur dioxide, fluoride, and photochemical oxidants. This review will be of value to those engaged in research planning. (668)

28. Air pollution injury of urban forests is of intensifying biological and economical importance in the eastern United States. The effects of air pollution on forest tree species have been summarized, and suggestions on how to reduce air pollution impact have been outlined. Managers of urban tracts should benefit from this information. (660)

29. Trees can reduce levels of atmospheric pollutants such as sulfur dioxide, but information on the capacity and efficiency of trees as air cleaning agents is limited. Seedlings of several hardwood species were fumigated with sulfur dioxide. This chemical initially accumulated in leaves and upper stems; but after 8 days, measurable amounts were transferred to roots. Identification of absorption sites and translocation paths of air pollutants in seedlings may aid in elucidating scavenger roles of mature trees. (664,665)

30. There are serious gaps in the knowledge of the relation between short- and long-term exposure of trees to air pollutants. Fumigation of hybrid poplar clones in controlled-environment chambers with either 5 ppm sulfur dioxide for 1-1/2, 3, or 6 hours or with 0.25 ppm sulfur dioxide for 6 weeks produced similar plant responses (growth; foliar injury) to the two concentrations. Determination of the sensitivity of plants by short exposures to a high level of pollutant may facilitate selection of genetically tolerant stock. (662)

31. The effect of air pollutants on all stages of growth and development of trees must be determined before the total consequences of air pollution on trees can be assessed. In continuing investigations of the effects of ozone on tree seedlings, it was found that growth of white birch seedlings was reduced by fumigation with 25 pphm ozone for 110 days. Growth was not reduced on fumigated seedlings of yellow birch, eastern cottonwood, bigtooth aspen, Japanese larch, or white spruce. (666)

32. Trees may condition contaminated air and reduce daily pollution levels. Approaches toward minimizing toxic concentrations in urban areas have been outlined. Research priority must be given to delineating potentials of trees for cleansing urban environments. (661)

33. There is increasing concern about acid precipitation because of its potential for long-term injurious effects on crop production. A recent symposium on this topic with speakers from several countries endeavored to determine the state of knowledge of the acidity phenomenon. Brief reports by these participants contain information valuable in determining research priorities. (663)

Recycling wastes—sewage effluent, sludge, and residues

34. Forests may offer advantages over farm crops for recycling sewage effluent, but few forest-soil systems have been tested. In southern Michigan, tests over three growing seasons on pine plantations and a hardwood site produced adequately renovated water below the root zone from effluent applied at 50mm/week, 3mm/hr maximum rates. Boron, N, and K levels increased in the red pine foliage along with increased growth. Boron toxicity may limit use of red pine sites. The tests indicate maximization of tree growth from sewage effluent should be subordinated to maintaining a viable ecosystem. (29)

35. There is an increasing need for environmentally safe methods of sewage sludge disposal. Energy development is increasing the areas of strip-mined lands needing reclamation. Use of slude on strip mined lands offers a solution to both problems. Studies in southern Illinois show that highly acid spoils can be revegetated and leaching of acids and heavy metals reduced by sludge treatments. Heavy sludge applications may cause excess nitrate nitrogen leaching, however. The studies have provided guidelines for a pilot project on the Shawnee National Forest. (25)

36. Winter irrigation of forests with sewage effluent would aid municipalities but requires adequate soil infiltration. Tests on sand soil plots forested with jack pine and scrub oak showed that effluent did infiltrate in most plots throughout the winter, and effluent distribution on the surface and within the soil mass was limited. However, nitrogen renovation was low as compared to the growing season. It can be concluded that winter irrigation of forest soils should be limited to areas where maintaining ground-water quality is not critical. (26)

37. Cities are turning to forest irrigation systems to dispose of sewage effluent, often without a thorough knowledge of environmental effects. Studies of soil chemistry after 9 years of effluent irrigation showed only nominal changes in potassium, sodium, manganese, exchangeable hydrogen, ozone, and phosphorus. No detrimental effects on the soil could be determined. The results can be used in planning effluent disposal facilities and forest irrigation. (28)

38. Introducing large amounts of phosphorus into forest soils through fertilization or sewage disposal can trigger phosphorus movement through the soil, eventually causing algal bloom and reduced water quality in streams and lakes. A method has now been found for determining the amount of phosphorus a soil can absorb safely. In a California test, contrasting forest soils showed more than fivefold differences in their capacities to retain phosphorus. The method can be used to identify soils where fertilization or sewage waste disposal treatments may damage downstream water quality. (27)

39. Conversion of farm livestock yards into confinement feedlots with many animals can increase the concentration of wastes in the feedlot runoff and kill trees in windbreaks that surround and protect these feedlots. Studies in Nebraska have shown that after 2 to 3 years of heavy feedlot use, surface runoff from feedlots into the adjacent windbreaks increased the soil pH and conductivity, altered the exchangeable cation status, added toxic organic substances and heavy metal cations, and produced biodegradable organics that reduced free oxygen in the soil. Combinations of these factors likely killed the trees on the windbreaks. Since overland flow, rather than lateral movement through the soil, transported the toxic substances into the windbreak, grading to divert the flow or selecting upslope locations for new plantings will help alleviate this problem. (155)

IMPROVING WILDLIFE, RANGE, AND FISHERIES HABITAT

Characteristics and values of plants for food and cover

40. What are the long-term effects of repeated winter, spring, and summer fires on growth and survival of longleaf pines and the yield and composition of understory vegetation? On a site near Alexandria, Louisiana, 12 years of biennial May fires resulted in signficantly greater height and diameter growth of pines. July fires eliminated most woody stems, although several pines survived. Herbage yield differences between burning treatments were not significant. Managers of longleaf forest lands, particularly those on which grazing or other uses are derived, should find May burning useful for improvement of longleaf pine growth. (177)

41. Native forages are deficient in quality during the winter in the southern forests. To remedy these deficiencies for wildlife and livestock, several introduced forages were studied for the Ozark and Coastal Plain forests. Cool-season introduced grasses improved forage quality, especially during winter. These perennial grasses produced more forage than native grasses under pine canopies. Specifically, elbon rye provided an abundant and palatable forage during winter, when native forages were not as plentiful, as nutritious, or as digestible. These results provide the manager with an opportunity for increasing deer and livestock capacity of Ozark and Coastal Plain forests. (208,216)

42. An inadequate source of high quality forage severely restricts the over-winter population of white-tailed deer in the South. The problem can largely be overcome by planting and fertilizing improved plants such as Japanese honeysuckle. In northern Arkansas, nitrogen fertilizer substantially increased the vegetation yields. Both nitrogen and P_2O_5 increased the crude protein contents of honeysuckle leaves. Ash, calcium, and phosphorus contents of leaves declined as levels of nitrogen were increased, but calcium, phosphorus, and magnesium all responded positively to P_2O_5. These results indicate that forest land managers can increase the deer carrying capacity of southern forests by intensive culture of honeysuckle on small selected areas. (214)

43. Range grass production varies greatly from year to year in the Southwest. For managers to maintain both grass and livestock production at optimum levels, the numbers of grazing animals must be commensurate with available forage. Monthly rainfall records at the Santa Rita Experimental Range were used to accurately estimate forage production. This technique can give forage predictions at much lower cost than field surveys. (162)

44. Semidesert rangelands are used for livestock raising, wildlife production, and recreation. All of these uses require maintenance of vegetation for food and cover. Research during the past 10 years found grass yield increased 52 percent following control of mesquite on semidesert ranges. This increased grass production repays control cost in about 6 years, and the increases are expected to continue 15–20 years. However, the number of cattle permitted to graze these improved ranges must be carefully regulated to avoid overgrazing and permanent damage to the range—especially during dry years. These results can be used in developing management guidelines for semidesert ranges. (164)

45. Development of effective grazing systems requires not only an understanding of the immediate response of important range plants to grazing, but also the rapidity of recovery following vigor reduction. *Festuca idahoensis* of moderately low vigor required approximately 3 years and *Agropyron spicatum* 6 years of complete protection to approach normal vigor. Recovery from very low vigor may take more than 6 years of protection for *F. idahoensis* and 8 years for *A. spicatum*. Maximum leaf length can be used as a reliable index of *F. idahoensis* vigor, and a combination of flower stalk numbers and maximum lengths indicate vigor in *A. spicatum*. These findings stress the importance for the range managers to either avoid the over-use which depletes plant vigor, or else incorporate in their grazing plan the long period of rest or deferment needed to permit recovery. (203)

46. Rosaceous shrubs are important cover, stabilization, and animal food plants in the vast Intermountain shrublands. However, information necessary for management is lacking. The general vegetative, floral, reproductive, hybridization, distribution and habitat, and use characteristics were described and reviewed for several plants of the rose family. A taxonomic key covering each taxon was shown. Review and original information on important rosaceous shrubs are now readily available. (160)

47. Chenopod shrubs are important cover, stabilization and animal food plants in the arid Intermountain area as well as on millions of hectares of worldwide alkaline ranges. However, information necessary for management is lacking. The present state of knowledge, new observations, and original hybridization data have been summarized for several woody Intermountain species. A key provides ready recognition of taxa. Hybridization, distribution, and habitat and use are given for each species; also possibilities for breeding and selection are discussed. Review and original information on important chenopod shrubs are now readily available. (161)

48. The proper timing for lifting nursery-grown planting stock is an important factor in the ultimate success of revegeta-

tion efforts on forest and rangelands. A portable oscilloscope was developed to determine the level of activity or dormancy of nursery stock or plants in the field. Oscilloscopic wave form appears to be related to periods of plant dormancy and activity for the conifers and deciduous trees and shrubs tested. Several potential uses of this technique are suggested for nurserymen and research workers. Potential uses of this technique include evaluation of cold tolerance, assessing effects of storage on nursery stock, and determination of plant activity in vegetation control projects where growth stage is critical to success. (172)

49. Establishing shrubs on ranges dominated by cheatgrass brome is difficult if not impossible. Scalping 4-, 8-, 16-, and 24-inch widths in cheatgrass allowed four species of plants to establish in a stand of cheatgrass. In general, the wider width scalps favored better shrub establishment. Application of this method by land managers will provide shrubs in large stands of cheatgrass and improve habitat for wildlife. (178)

50. Revegetating disturbed areas is a crucial problem in the western United States. A list of plants suitable for revegetating depleted rangelands, mine and construction sites, logged and burned areas was prepared. Most encouraging results have been achieved when species were selected from plant communities that occurred near the problem sites, or have developed under similar climatic and edaphic conditions. This information will help managers in revegetating disturbed areas. (201)

51. More than three-fourths of the juniper-pinyon ranges of the western United States are severely depleted of grasses, forbs, and palatable shrubs necessary to thrifty big game herds. Indications from 20 years of study in Utah show that a competitive grass, forb, and shrub community in combination with browsing pressure is the key to preventing juniper and pinyon from regaining dominance on chained and seeded areas. This biological competition along with yet unstudied insects and diseases can make juniper and pinyon lands more productive for wildlife and livestock. (217)

52. Wildlife have not been adequately considered by economic analysis in forest management alternatives or in resolution of multiple-use conflicts in eastern forests. A technique was developed in the Monongahela National Forest of West Virginia using four species of game and seven major forest types. Timber/wildlife relationships were numerically rated for systematic consideration of management alternatives and to more accurately determine trade-offs between timber and wildlife values and between species of animals with different habitat requirements. This technique will assist the land manager in evaluating management alternatives and in showing the step by step logic of his decision to landowners and the public. (175)

53. Unknown variation in nutritive values of range forage represents a barrier to achieving efficient forage utilization. Information was provided on seasonal and locational variation in forage quality of numerous key grass, forb, sedge, and shrub species in central Oregon. The results obtained, together with the ranchers' knowledge of available forage, provide an improved basis for optimizing use of high quality forage through scheduling kinds and time of range use. Such results should also aid in alleviating the demand for late season protein supplementation. (182)

54. Lack of guidelines for managing lodgepole pine ecosystems throughout the Northwest for wild and domestic ungulates limits the development for optimum use of forest resources. Relationships of timber harvesting techniques, understory production, and domestic and wild animal uses were summarized. Timber harvesting and cattle grazing practices were recommended to optimize ungulate productivity. (159,165)

55. Curlleaf mountain-mahogany, although an important browse and cover plant for wild ungulates in the Northwest, is a species for which almost no management information is available. Germination capacity, possible causes of seed dormancy, methods of breaking seed dormancy, and initial seedling root and top growth relationships were determined. Relationships among curlleaf mountain-mahogany ecosystems were examined, and habitat types, their phases and successional stages were delineated. It was also determined that the existence of this species and the communities it dominated were dependent on fire resistant rocky sites where old trees provided available seed sources in case fire decimated adjacent stands. Information from this study will enable managers to protect existing stands and encourage their expansion, as well as propagate new stands where desirable. (166)

56. Production of larger quantities of higher quality fruit is the ultimate objective in wild huckleberry management, but we need more information about the natural and cultural factors affecting huckleberries. Results of studies in Oregon and Washington show that huckleberries have numberous robust rhizomes that sprout vigorously after light surface fires, that huckleberries are susceptible to excessive micronutrients, and that sweetness of huckleberries is greatest late in the season but is apparently not affected by shading. This information should help forest managers devise cultural prescriptions that enhance the quality and quantity of huckleberry production. (198)

57. Prescribed burning is used in the southeastern United States to promote the growth of legume plants which produce seed important as quail food, but the basic effects of heat on legume seed germination are poorly defined. Moist heat increased germination of eight species and two varieties of legume seed while dry heat increased germination in seven species and two varieties. Thus, no broad prescription can be made for enhancing germination of all legume seed but prescriptions will depend on the species involved. (189)

58. The demand for red meat has stimulated interest in using pine-wiregrass forage for cattle production and in determining the nutrient content and digestibility of the forage. Crude protein appeared useful for predicting digestibility of grasses but not of forbs and shrubs. A comparision of *in vivo* and *in vitro* techniques to evaluate forage throughout the April to October grazing season resulted in similar findings. Poor quality of the forage was indicated by crude protein levels of less than 8 percent and dry matter digestibility of less than 40 percent during most of the grazing season. Land managers cannot rely solely on pine-wiregrass forage as a food source for cattle. (187)

Fish habitat resources

59. The effects of chemical fire retardants on fish in streams is not known. A computational system that permits a rapid estimate of the amount of hazard to game fish was developed based upon (1) the amount of retardant that enters a stream and (2) the discharge rate and average velocity of the stream. Application of this system will allow assessment of the effects on fish habitat of retardants that may enter a stream during fire suppression activities. (730)

60. Measuring or weighing live fish can harm them. A photographic technique was developed for studies where fish were chronically exposed to toxicants, and changes in size and weight were one of the response measures under study. Actual dry weights of test fish were correlated with photographically measured indices of lateral area. The equation obtained has a coefficient of determination of 0.95, and the technique has been used successfully in tests of chronic oral toxicity. (227)

61. Fish spawning will be reduced if river bed conditions are not improved in the steep mountain lands in the Idaho Batholith. Research found that land uses in this sensitive area must be carefully planned to avoid adding more sediment to a stream than it is capable of transporting. A system of programmed land uses was recommended to avoid degradation of these aquatic environments. (228)

62. Containerized planting in the South has not been fully developed because of a lack of economic incentive. Results of several recent tests indicate containerization can meet the criteria necessary for full southern acceptance: an extension of the planting season, better early seedling growth, and an adaptability to automated planting. This information should serve as a stimulus and guide to those considering the use of container planting. (876,874)

Wildlife habitat resources

63. The effect of fire on wildlife is one question that has arisen with the introduction of prescribed fire into wilderness areas. Because of its position at the top of a food chain, the pine marten (*Martis americana*) appears to be a good "barometer" of the health of an ecosystem. Under natural conditions, fire does not maximize marten populations locally, but it does maintain sufficient forest diversity to perpetuate the species. Wildland managers would do well to consider the needs of the marten in comprehensive, long-range plans for the forest ecosystems it inhabits. (726)

64. Southern pine forest ranges commonly provide adequate forage for yearlong grazing by cattle and afford habitat suitable for white-tailed deer; however, the question of how intensive pine culture affects multiple land use has not been answered. In a study near Gulfport, Mississippi, cultivation and fertilization for pine revegetation not only increased pine growth at age 12, but browse desirable for deer was more abundant. Herbage production and browse undesirable for deer declined with cultivation and fertilization. With proper management, intensive pine culture appears to be compatible with browse maintenance. This provides encouraging evidence that multiple-use interests can be served with proper management. (293)

65. Profits largely determine management decisions on commercial forest lands. Past decisions have, therefore, favored timber production over wildlife, and land management practices advantageous to wildlife were usually incidental. The current trend in forest management in the South is to include game and charge for hunting. Most forest land owners have to be assured of a monetary return before making adjustments to improve wildlife habitat at the expense of timber. (246)

66. Because deer consume food at different rates and foodstuffs vary in quality through the year, the deer are hard pressed to maintain a nutrition level necessary for their optimum production. As early as November, deer may consume barely enough digestible dry matter to satisfy basal energy requirements because of the low digestibility of many range forages and the diminished rates of food intake. Management practices that favor an increase of digestible dry matter, retention of fungi, hard and soft mast producers and desirable evergreen plants, and the establishment of food plots containing fertilized plantings of cool season herbages have demonstrable advantages to deer. (282)

67. Bachman's Warbler, an endangered species, is on the verge of extinction. An intensive search was made in I'On Swamp, formerly an important nesting area, and other portions of the Francis Marion National Forest. No birds were found, but much of the habitat appeared suitable for the species. The search, the most thorough ever made, emphasized to land managers and the public the dire status of the species. (247)

68. Forest managers need to know how different management alternatives affect wildlife habitats. A range analysis conducted in midsummer on adjacent clearcut and selectively cut areas in the Ridge and Valley Province of southwestern Virginia showed that plants preferred by white-tailed deer were 2.6 times more abundant in a 6-year-old clearcut as compared to an area selectively cut 5 years prior to measurement. Increased shrub numbers decline on the clearcut as the vegetation grows beyond reach of the deer, and the dense cover largely precludes development of understory vegetation. Thinnings are suggested as a means for maintaining browse production for these young forest stands. (231)

69. Whether to collect rumen samples to study the foods selected by deer from a particular area or rely on regionwide studies already completed is a question management biologists repeatedly face. A comparison between local samples within the Southeastern Coastal Plain of South Carolina and regional samples from sites between Florida and Maryland indicated that such a decision will depend on two factors: (1) The feasibility of collecting local samples, and (2) whether the biologist considers it important to know what specific plant species deer feed on. If the biologist is only interested in food categories, e.g., twigs, leaves, fungi, forbs, and grasses, regional collections are adequate. However, if the biologist must know the specific plant species deer feed on, local sampling will be required. It is essential to determine whether regional findings are applicable to local areas. (248)

70. In the Ridge and Valley Province of southwestern Virginia, acorns comprise about 70 percent of white-tailed deer fall and winter diet. In years of poor acorn production, however, it is important to know that foods are substituted. During poor oak mast producing years in southwestern Virginia, deer substituted large amounts of leaves of prostrate evergreen plants, shrubs, and mushrooms. Deer relying on mast-free diets had difficulty meeting minimum energy requirements for maintenance. The availability of acorns in the winter diet increased the estimated digestible energy to 3.1 kcal/g, a level adequate to meet the maintenance energy requirements. It is important that habitats be managed to assure an adequate supply of alternate high energy foods during times of mast scarcity. (252)

71. To improve deer habitat, the land manager needs to know what foods are available to deer over a range of forest types and conditions. Up to now, this information has not been available in the southern Appalachians. During the fall and winter months, a survey of 14 forest types on the Chattahoochee National Forest indicated the average yield of deer food was 109 pounds per acre.

Twenty pounds of the total were preferred foods. Forest types producing the largest amounts of preferred deer foods were loblolly pine, sweetgum-yellow-poplar, oak-hickory, and oak-pine. This information will aid in realistically determining carrying capacities of these forest types for deer. (250)

72. A study of the browse production on the Oconee National Forest in central Georgia indicated that during winter months the average yield of browse for all forest types was 143 pounds per acre, with 128 pounds contributed by "choice" foods and the remainder by "other" species. On an area basis, the sweetgum-yellow-poplar type produced the largest amount of "choice" species followed by the Virginia pine and loblolly pine types. Most important of the "choice" foods were Japanese honeysuckle and greenbrier followed by blackberry and blueberry. A knowledge of the relative values of forest types as deer range helps the land manager determine those types in need of habitat management. (251)

73. The common raven is a relatively scarce nongame species in the eastern United States that inhabits the narrow belt of mountains from northern Georgia to northern Pennsylvania. No quantitative data have existed on which to base management decisions concerning this bird. Density, distribution, food habits and habitat requirements were studied at several Virginia sites. This information provides a factual basis for planning additional research needs and making management decisions for a unique wildlife species. (249,254)

74. Construction of suburban areas often requires manipulation of natural vegetation. Information on wildlife population responses to changes in vegetation is lacking. Because landscaping is costly, such knowledge is important to planners and builders interested in providing a quality environment to homeowners. In Reston, Virginia, within four types of suburban habitats, the densities of breeding birds appeared to be directly related to the amount of shrubs. However, clumping of vegetation was thought to be more important than amount of vegetation in explaining variations between habitat in density. An inverse relationship was found between bird numbers and the amount of asphalt, cement and buildings. These relationships show that bird numbers are related to measurable habitat features. With better resolution of these relationships, planners can more confidently commit time and money to providing bird habitat where it is wanted. (255)

75. Snow depth limits availability of forage for deer on many winter ranges in North America. To decrease snow depths, carbon black was sprinkled on the snow in critical areas of deer winter rangers in Colorado. Snow melted to bare ground, exposing forage for deer 1 month earlier on the treated areas. This technique is a means of increasing forage availability to deer when they are in poorest physical condition and food needs are most critical. (274)

76. Logging in ponderosa pine is changing the environment of the Abert and Kaibab squirrels. Three studies in Arizona quantified the cover requirements of the squirrels in terms of basal area, trees per acre, size of nest tree, canopy coverage, and size of trees surrounding the nest tree. Forest managers can use the data to evaluate the quality of Abert habitat on 11 million acres of ponderosa pine in Arizona, Colorado, and New Mexico and of the Kaibab habitat on the Kaibab Plateau in northern Arizona. (241,265,273)

77. In recent years, the amount of wildlife literature accumulating in professional journals has made it difficult for field biologists to maintain a reference library. An alternative is to prepare bibliographies on subjects that are needed most. Such a bibliography, recently published, contains 390 references on research and management of important wildlife species and habitats in Arizona and New Mexico from 1913 to early 1975. This information provides the manager with a convenient desk reference to aid him in planning, environmental assessment and management of the wildlife resources. (266)

78. Information about requirements of cavity nesting birds was summarized for Arizona and New Mexico forests. Traditionally, dead or unmerchantable trees are removed during a timber sale because they are a fire hazard. Managers now have information that shows how important these trees are to maintenance of populations of cavity nesting birds. This information can be used in planning timber harvest, environmental analysis, visitor information, nature interpretations, and bird watching. (279)

79. The cottontail is an important food of many predators in the deserts of Arizona. Up to now, management of this species has been hampered by lack of information about the food and water requirements of this important prey. Moisture content and stage of growth of the plant apparently influenced food selection. Cottontail survival was found to be limited more by availability or abundance. With these new insights into the energy and water requirements, management of the cottontail in desert habitats is possible. (286)

80. Nutritional values of mule deer diets on southwestern ponderosa pine summer ranges were needed by foresters and range managers to evaluate impacts of timber harvesting on deer habitat. Chemical analyses and *in vitro* digestibility data were obtained for forages used by mule deer during the summer when the deer generally occupy ponderosa pine types. Nutritional quality of deer diets on ponderosa pine summer ranges declined sharply from spring to late summer. These declines were not severe enough to cause deficiencies. Overall, the nutritional quality of the summer diet of deer in ponderosa pine ranges was adequate. (224,288)

81. Sharp-tailed grouse need high energy foods to survive temperature extremes during winter. Relationship between cover requirements and loss of body heat have not been previously determined. A grouse in −20°C. temperatures and winds of 8 miles per hour can, through changes in posture or cover, vary energy loss between 142 and 319 kilocalories per day. The bird uses dense vegetation or snow as insulation to reduce heat losses during extreme cold weather. Winter losses in grouse populations can be reduced if adequate winter cover is maintained. (240)

82. Elk in the Rocky Mountains are associated with timbered habitats; consequently, coordination between timber harvesting and management of elk is needed. Elk may move considerable distances to avoid disturbances associated with logging in the ponderosa pine forests of Montana. Research initiated in 1970 provides land managers with alternatives to minimize disturbances to elk during logging operations. (258)

83. Pocket gophers were thought to compete with livestock for forage in mountain rangelands of the Wasatch Plateau. Total forage production did not increase significantly on an area when gophers were excluded for 31 years. However, the kinds of plants growing in the area following gopher control were differ-

ent from those growing in areas inhabited by gophers. New gopher mounds provide suitable habitat for a variety of annual and perennial plants that are important livestock foods. The importance of the gopher in maintaining a variety of livestock foods in mountain rangelands has been determined. (185,260)

84. Techniques are needed to study behavior and movements of endangered timber wolves in Minnesota. Radio-tracking of wolf packs for several years provided much valuable knowledge. For example, we now know that the sense of smell is used by wolves to maintain a territory. These results provide the manager with information about wolf behaviour and management that will help ensure continued existence of the wolf. (271)

85. The wolf is a species threatened with extinction in the 48 contiguous States. The factors governing intrinsic population regulation in wolves are not well known. Males comprised 66 percent of wild wolf pups from a saturated, high-density wolf range in northeastern Minnesota, possibly reflecting disproportionate conception of males. Packs from areas of lower wolf density in other areas of Minnesota had equal sex ratios of pups or a slight but statistically significant preponderance of male pups. Study suggests that disproportionate sex ratio is related to whether or not wolf populations are near saturation level for the region. (262)

86. Managers need checklists of local fauna to make accurate environmental assessments, to develop land use plans, and to implement multiple-use management on public lands. The wild fauna in the Pinyon-juniper and Northern hardwood forest types have been described. This information is a basic step in improving planning and management of all wild fauna on forest and rangelands. (243,275)

87. To promote conservation of birds of prey, their role in nature needs to be understood. A study in Minnesota determined food habits, animal pest consumption, use of these birds as ecological indicators, and their value for recreational and esthetic enjoyment. This information presented to the public through this popular format should help lessen the continued serious persecution of raptors in Minnesota. (244)

88. White-tailed deer populations have declined in northeastern Minnesota from highs in the 1930s and 1940s in spite of ever intensifying forest management activities which should theoretically improve habitat. A recent study details fall and winter habitat selection forage preference during 1970 through 1972. Open cut-over and deciduous-dominated communities were used most frequently in early winter, and conifer-dominated stands, especially those containing balsam fir and white-cedar were used more frequently in late winter. Mountain maple, red-osier dogwood, and round-leaved dogwood were most used in late winter. This study suggests that this mature forest is producing sufficient browse and conifer cover to allow the diminishing deer population to overwinter in small scattered groups rather than concentrate in classic yarding situations traditionally observed in the area. (290)

89. In spite of the importance of bears as a recreation, esthetic, economic, and ecological resource, their biology and habitat requirements are known in only a very general way. Basic information about their biology, sociology, and food habits has been pictorially presented and the importance of a field research program on the bear detailed. These studies will provide information on the behavioral and physical adaptation and the environmental requirements of black bear to aid game and land managers to assure the future of the black bear in the Lake Superior Region. (277)

90. Eventual scarcity of squirrel dens will ensue from most hardwood timber management systems unless they include ways to provide for den maintenance. Choice of the best way to manage for dens depends on intensity of the timber management and the acceptable degree of risk that a given way will not work. Standards for numbers and distribution of dens are recommended, and management options pertaining to four different levels of management intensity and risk are described. Although the options are designed primarily for even-aged forests, the two more-intensive options can be applied in any forest stands where dens are needed. (278)

91. Many mule deer herds have low reproductive rates because range conditions have declined from overuse. In southern Idaho, deer and livestock numbers were reduced to range carrying capacity and fawn production increased as range conditions improved. Average fawn production increased 47 percent among yearlings and 42 percent among 2-year-olds and averaged 20 percent for all age classes of does combined. Managers can use this information to gain public support for reducing livestock and deer on overstocked ranges. (259)

92. The effect on mutton of spraying DDT to central forest insects is unknown. DDT residue was sampled in weaned lambs grazing in mixed conifer forests aerially sprayed with DDT to control Douglas fir tussock moth. DDT residue was highest in fat of lambs grazing sprayed herbage for 2 weeks; residues then decreased in lambs grazing for longer intervals up to 16 weeks. Residues in lambs grazing sprayed herbage for longer periods did not fall below acceptable tolerance levels after 18 weeks on unsprayed herbage. These results will aid administrators and stockmen in future planning of livestock grazing practices on forest ranges which may require application of chemical pesticides. (284)

93. To diagnose the health of wild animals, field biologists are using techniques and equipment developed by medical researchers. Cooperative studies between these two groups are providing new insights into understanding relationships between the general health of wild animals and their environment. For example, twelve common tests of human blood samples were effective in diagnosing the general state of elk and moose (wild mammal) health. This new research approach holds considerable promise of providing the concepts and tools for evaluating the condition of wild animals and the condition of their range relative to their needs. (230,257,269)

94. Nongame birds have been a neglected ecological and recreational resource, which until recently, have not been seriously considered in decisions on land management. Initial guidelines for management of forest and range habitats for nongame birds have been developed for many locations. Twenty-eight state of knowledge summaries about management covering a variety of special topics and major ecosystems including interactions between people and birds; bird behaviour and habitat management; the influences of forest and range management practices on bird populations; and agency management programs for nongame birds. These results provide managers, biologists, planners, teachers, and the general public with authoritative summaries of how to manage forest and range habitats for nongame birds. (204,222,226,256,283)

95. Guidelines for red squirrel management in white spruce forests of interior Alaska are not available. Population response of red squirrels to clearcut and shelterwood sylvicultural systems in interior Alaska was determined by counting the population before and after cutting. Following harvest, all territories from the clearcuts were vacated and the number of squirrels in the shelterwood decreased from 1 per 0.69 ha to 1 per 2.0 ha. The squirrel population in the adjacent control area and along the cutting area boundary remained stable. These comparisons help define management alternatives and resolve trade-offs among them. (292)

96. Moose are an important resource in Alaska and evaluations of browse production and use are needed to assess moose habitat. On the Tanana River flood plain near Fairbanks, 38 and 113 kg/ha of available hardwood browse were present in 8- and 15-year-old stands respectively. Moose consumed about 55 percent of the available forage in both areas during the winter of 1974–75. Willows were the most abundant shrub and in turn provided the most winter forage. These evaluations help establish moose management guidelines. (291)

97. Although cultivation and fertilization can increase growth of southern pines, questions have existed concerning the effects on understory vegetation. In a pine plantation in Mississippi 12 years after cultivation and fertilization treatments, deer habitats were better than on the control. Browse species became more plentiful and reduction of undesirable browse improved accessibility for all forest users. Thus, intensive pine culture and browse management seem compatible throughout much of the southern pinelands. (293)

Rangeland management

98. Multiple use of the southern pine forests requires complex planning. Range and wildlife resources were described and related to forest management practices. Site preparation, reforestation, thinning, clearcutting, prescribed burning, and fertilization techniques provide single- or multi-resource yields, depending on the land manager's objectives. Judicious multiple-use planning provides benefits to cattle and wildlife with few concessions necessary from lumbermen. (305)

99. Forbs comprise a large proportion of the total herbage on many high elevation cattle ranges in the Bighorn Mountains of Wyoming. Many managers consider them to be undesirable forage for cattle, and herbicidal control of forbs is an accepted range management practice in this region. This study showed that while 2,4-D significantly increased the ratio of grasses to forbs in the herbage, it did not influence total herbage production. Yearling steers grazing the treated ranges had the same grass-to-forb ratio in their rumen as steers grazing untreated ranges, and daily weight gains were also similar. The lack of a significant increase in forage production, of alterations in the composition of the steers' diet, and in their weight gains indicate forb control is not necessarily a desirable range management practice, especially under light rates of stocking. (221,310)

100. Because of the high cost of southwest semidesert ranch property and the large unpredictable variation in forage crops, range livestock production appears questionable. Research found that proper stocking can make a ranch operation stable, simple, income producing, and of reasonable risk. Ranchers in Arizona should be encouraged to continue to graze livestock on semidesert range. Forage on these ranges uses solar energy and the forage cannot be harvested economically by machine. Therefore, the most efficient use of the forage is grazing livestock. (301,302)

101. The dormant plant period from fall through early spring is the most critical period for adequate livestock feed and also the most expensive because of the need for supplements. There is a need for plant species and management systems which can reduce supplement feeding costs or provide better livestock maintenance. Cattle, grazing Sherman big blue grass ranges in Colorado during the cold winter period, gained weight in late fall with or without a protein supplement. During late winter and early spring, they lost some weight. Big bluegrass could be used for fall grazing to replace native range. The native range is then used for better winter and spring livestock management. Costs are reduced and more animals can be carried over winter or a fixed number of animals can be maintained on fewer acres. (295)

102. Sheep numbers permitted on high mountain ranges have been declining for several decades because of conflicts with watershed, wildlife, and recreational values. Investigations into the possibility of utilizing traditional spring-fall range on the Upper Snake River Plain in Idaho for summer grazing indicated that sagebrush-grass range can withstand heavier grazing pressures in the summer than in the spring. Heavy grazing (80 SD/A) was more damaging to grass and forbs in early summer than in late summer. Moderate grazing (30–40 SD/A) over a 5-year period did not adversely affect the vegetation, and maintained ewe weights. Summer grazing of sagebrush-grass range can provide ranchers with opportunities for maintaining or increasing sheep numbers despite restrictions on high mountain ranges, if they have an excess of spring-fall range. (298)

103. The western sheep industry is limited by the increasing constraints imposed on grazing high-mountain summer ranges. Studies on the Centennial Mountain range in Idaho show that traditional spring-fall range can be grazed profitably by sheep during the summer months if the lambs are weaned early in July and placed on green feed. Over a 5-year period, ewes grazed on sagebrush-grass range gained about 5 lbs. during the summer while those on high-mountain summer range gained about 10–15 lbs; however, these body weight differences were negligible the following spring. Wool production was not affected. Summer grazing of spring-fall sagebrush-grass range by sheep appears both a practical and profitable option for alleviating shortages of traditional high-mountain summer range. (307)

104. Grazing inevitably alters, to varying degrees, wildland vegetation and it is primarily by the establishment of protected "natural areas" or reference areas, that we are able to maintain representation of undisturbed plant communities to serve as a basis for judging the effects of man's perturbations. A new publication reviewed the literature regarding rangeland reference areas, summarized current programs in the United States and Canada, and outlined a program to encourage establishment and preservation of such areas. It serves as a course of information for those interested in the preservation of rangeland natural areas. (299)

105. Ponderosa pine-bunchgrass ranges have been grazed for over 100 years, yet no systems or levels of grazing have been prescribed for resource managers. An 11-year study of plant and animal responses to systems and levels of cattle grazing snowed forested range was improved by deferred rotation; there was

little change on intermingled grassland openings. Big game use decreased as cattle stocking increased. *Carex geyeri*, the most valuable forage, was favored by light deferred rotation. Range managers have six alternative grazing methods for ponderosa pine-bunchgrass range management with identified impacts and trade-off values for associated resources. (308)

106. Ranchers need additional information on livestock performance on ponderosa pine ranges. Responses to cattle grazing in eastern Oregon under three levels of stocking were compared. Levels of stocking produced different degrees of forage utilization but grazing systems did not. As stocking increased, herbage production and cattle gains decreased. Systems of grazing had no effect on cattle gains. Deferred rotation improved ground cover in the grassland type, but had little effect on yield. In the forest, yields of forage were diminished by season-long grazing compared to those under deferred rotation. The results will aid range managers in forecasting the results of investments in improved woodland grazing techniques. (309)

107. Implementation of available knowledge of range management techniques in the central and southern Rocky Mountains has been slow because publications were scattered or incomplete. Comprehensive, in depth reports have been prepared for seven important range types in this area. These reports summarize published information applicable for range management of the seven range types. They also contain valuable knowledge accumulated through experience and familiarity with specific range situations. Information from these reports will permit better range management in this area. (163,190,-220,296,303)

IMPROVING SOCIAL AND AMENITY VALUES

Environmental amenities—landscapes and open space

108. Good communication in land-use planning requires common agreement among the various disciplines involved about the meanings of relevant terms and concepts. A glossary has been designed to facilitate a common understanding and acceptance of the meanings of current wildland planning terminology. The glossary contains definitions of 1400 terms—with 600 other terms cross-referenced to more preferred usages. The glossary provides a ready reference source where planners and managers can keep pace with the evolution of wildland planning terminology. (323)

109. Land management to enhance or protect esthetic values requires procedures for delineating the terrain visible from one or more points in the landscape. Research has developed a computer program called VIEWIT, that analyzes the slope, aspect, and area that can be seen from selected locations. The information is printed on a map overlay that makes it easy to compare VIEWIT results with other land-use planning considerations. The system may be used by those having remote terminal access to the USDA Fort Collins Computer Center. VIEWIT has been used to plan timber harvesting operation, scenic trainways routes, transportation system alternatives, recreation developments, and fuelbreaks. (325)

110. Multiple-use of the lodgepole pine ecosystem requires an understanding of how the species should be managed to enhance esthetic quality. Individually and collectively, lodgepole pine tends to be modest and unassuming in its visual composition. Research has shown how esthetic values increase when the species is integrated with other elements of the landscape. Lodgepole pine is frequently associated with Rocky Mountain landscapes and thus results of this research have applicability for improving esthetic quality over a wide geographic area. (313)

111. Planning for recreation and other uses requires projections about the future. Using the Delphi research technique, a panel of 400 experts provided forecasts of 125 future events about the Nation's natural environment. These perspectives on the future provide a basis for dealing more effectively with future environmental problems. (319)

112. Europeans are ahead of the United States in land use zoning to maintain a range of conditions and opportunities. Europe's small-scale and highly humanized landscapes often have such coarse visual textures that timber cutting blends into, rather than mars, the scene. Furthermore, cutting areas are usually so small that stands of many ages are often visible from a single point—making the sustained nature of timber management clear to even skeptical viewers. The European experience shows that lands can be managed for high levels of both amenity and material benefits. (326)

113. Planning for recreation and other land-uses is a complex task. Analysis of land-use planning processes in Holland suggested that the required decisions need to involve the interaction of five groups: diverse specialists, interest groups, analysts, planners, and decisionmakers. For best results, participants must understand the limits of their roles, and communication among the groups must emphasize the meaning (rather than the details) of related data. A computer mapping technique for identifying and defining land-use alternatives is described. The method is applicable to many land-use planning situations in the United States. (327)

114. For much of the world, recreation must be subordinated by more pressing priorities. Analysis of the situation indicates that poor nations cannot justify substantial sacrifices to gain international tourism, to maintain options involving recreational lands for a later stage of economic development, or to preserve land-based examples of a national heritage. Analyses such as these can help set priorities in international forestry and land use planning. (328)

115. Land management requires procedures for monitoring changes in land-use patterns. Research has described the changes in vegetation and land-use in Massachusetts for the 20-year-period 1952–72. The research describes a system for classifying land from aerial photography. Areas as small as 3 acres were classified in 28 broad types and 104 detailed types of land areas. Statistics and maps are available for land-use planning at the town, county, and State levels. (314,315,316,317,318)

116. An important aspect of recreation demand, and one that consumes significant parcels of attractive natural landscapes, is the second-home recreation market. Rapid growth in the construction of second-homes in the Northeast has had significant positive impacts on the economy, and negative impacts on the social and environmental aspects, of rural areas. Research has shown that second-home development clearly accelerates change in land-use away from farming and forestry. Policy issues and additional research-needs are identified for future planning and research. (321)

117. Land use planners in and around urban centers need efficient techniques to manipulate and analyze the huge amounts of data involved in planning decisions. Research has developed a *Metropolitan Planning Model* that allows planners to analyze areas threatened by natural and man-made hazards, and to define areas that are specifically suited for development without undue degradation to the ecosystem. The model can be used to predict land use trends resulting from planning decisions from urban sprawl, and therefore, is extremely relevant to decisions related to the social and economic well being of people in densely populated areas. (311,312)

118. Growing demands on land resources have resulted in the problem of how to best allocate land for various combinations of uses and benefits. Interviews with Connecticut residents provided the basis for defining degrees of public acceptability toward existing land uses such as open land, forest products, agriculture, mining, recreation, wildlife, and rights-of-way. The results provide a useful evaluation of public acceptance for various land use policies. (324)

119. Increasing public awareness, and resultant legislation, has put forth a challenge to planners, designers, and scientists to insure that intangible or amenity-values enter into the landscape decisionmaking process. Results of 21 papers comprise a state-of-the-art report on landscape values, perceptions, and resources. Results can be used by land planners to better identify and incorporate landscape values in regional plans involving a multiplicity of resource management interests. (329)

120. Traffic noise is the most widespread form of audio pollution and attempts to reduce it at the source have been only partly successful. Tests in Nebraska show that wide belts of tall, dense trees can reduce sound levels up to a half and combinations of tall dense trees, shrubs, and landforms 10–12 feet high can reduce it as much as two-thirds. Sound barriers close to the sound source were more effective. Effectiveness of tree-covered landforms is now qualified and is being used by landscape architects, highway engineers, foresters, and other to reduce noisy traffic situations to more acceptable levels. (805)

Environmental amenities—wilderness

121. Increasing use of remote backcountry recreation sites in the Northeast is resulting in a loss of the thin soil mantle and destruction of the ground-cover vegetation. Fencing, fertilization, and liming—plus various combinations of these treatments—were tested as a means of reestablishing ground-cover vegetation on bare mineral soils. Results indicate that a combination of fertilization, liming, and fencing was the best treatment for restoring ground vegetation. (330)

122. In order to determine management strategies for the interior zone of the Boundary Waters Canoe Area in Minnesota, knowledge of the composition, structure, and relationships of the plant communities is needed. Research has identified the major upland plant community types in 68 stands disturbed by logging and in 106 undisturbed stands in the area. Managers not only can use this information to evaluate possible management strategies within the area, but also to relate ecological information to stands outside of the area—and thus broaden the management implications of the data. (331)

123. Management options for the Boundary Waters Canoe Area in Minnesota require ecological information about plant communities, their development, and the wildlife they produce. Scientists have summarized both the vegetation and wildlife research results since 1967. Results indicate that composition of the plant communities is largely determined by: time since last disturbance, composition of the disturbed community, and severity of that disturbance. Overall vegetation, predators, and prey are all adapted to a pattern of recurring disturbance by fire. The results provide management with a clearer understanding of the factors that influenced present conditions, and thus a firmer basis for managing these environments in the future. (335)

124. Efforts to determine desirable modifications of wilderness use patterns through on the ground trial-and-error are time-consuming, often inconclusive, and generally inefficient. Research has developed a tool that enables a manager to test a variety of possible policies in a short time with a simulation model. Detailed information on use patterns and congestion enables evaluation and comparison of alternatives. This user's manual describes three versions of the model and presents the computer programs required to operate the model, which is a useful, practical tool for wilderness management. (336)

125. Management efforts to modify wilderness use patterns need some way of measuring actual use to identify problem areas and determine the success of attempts to shift use. A study of use patterns in part of the Selway-Bitterroot Wilderness in Montana discovered that unmanned trail registers, a very common way of gathering use data, are much less reliable than thought. Only 28 percent of the visitors registered. Day-use and horse use would be particularly underestimated by trail register data. Trail register data need to be viewed suspiciously and used only after field checking. If the low compliance rates found in this study are widespread, alternative ways of obtaining reliable use information will need to be developed. (333)

126. The demand for hiking has been growing rapidly at the same time hiking opportunities have been declining. Short trails, close to population concentrations and zoned to separate mechanized and unmechanized visitors, seem to be most needed, based on a review of research knowledge about trail use and users. (334)

127. The impacts of recreational demand on the user and the resource of the Boundary Waters Canoe Area of Minnesota are a major concern of resource managers. Analysis of the situation indicates that heavy use and congestion are confined to specific locations and time periods, and that paddle canoeists strongly object to meeting motorized parties. Results are helping planners to understand patterns of recreational use and what to do to minimize dissatisfaction among user groups. (332)

Managing recreational opportunities

128. Accurate knowledge of the camping market is increasingly critical for successful development and competitive operation of commercial campground enterprises. Based on a nationally representative sample of 2,313 households, the total camping market is estimated to include 14.3 million households of active campers, 6.1 million who are temporarily inactive, and 6.1 million who are potential additions to the market. Research has documented the popular image of camping as held by each of the major segments of the market, and has examined the reasons why households permanently or temporarily drop out of the camping market. This information is vital to present and potential campground market investors and operators. (347)

129. Pricing of outdoor recreation services is an important policy issue for public agencies and a major factor in commercial recreation enterprises. This study at a State park in New Hampshire examined the effects of charging premium prices for waterfront campsites. The premium rates increased park earnings by 29 percent, while the use of waterfront sites declined by only 4 percent. If a similar program of differential fees were applied throughout New Hampshire's 212 commercial campgrounds, the estimated increased profit would be almost half a million dollars. (348)

130. Demand for water-oriented outdoor recreation continues to increase—especially near urban areas. Consequently, municipal watershed managers are under pressure to open their watersheds and reservoirs for recreational activities. Problems and opportunities are reviewed for watersheds on which varying amounts, to no amount, of recreation is permitted. Information is provided that managers can use to develop contingency plans for various alternatives regarding recreational opportunities on their land and water resources. (345)

131. Managers continually seek ways to clarify and improve the decisionmaking process in recreation-resource management. Based on results of a survey of 29 top decisionmakers, four broad areas are involved in such a process. These areas listed in ascending order of difficulty to contend with, are: political influences, characteristics of the physical resource, supply opportunities, and recreation demand projections. Information provides insights into management priorities and related research needs. (350)

132. Although interpretive presentations can greatly enhance the recreation experience, methods have not been available to evaluate the effectiveness and to identify opportunities to improve these presentations. Tests have shown that field personnel can observe and record level of effectiveness and audience attention to various kinds of presentations. Results can be used to help diagnose strengths and weaknesses of such presentations. (341)

133. To be effective in interpretation of natural environments means to create desired effects in an audience. Research has described how to clearly specify what those desired effects should be, how to design messages to attract and hold the attention of the intended audience, and how to evaluate how well the desired effects are accomplished. The results are applicable over a wide range of environmental interpretation situations. (356)

134. To gain a better understanding of public reaction to information and education displays, average viewer time was measured for a variety of exhibits. The longer the message per exhibit, the less time was spent observing it. Study results are intended to assist professionals in the design and presentation of exhibits about people's relation to their forest resources. (353)

135. The economic value of nongame birds is often overlooked in urban development program. Research has shown that in 1974, expenditures for birdseed, binoculars, feeders, books, field guides, and camera equipment, amounted to 500 million dollars. Results provide information to justify the preservation and enhancement of wildlife habitats for nongame birds in urban environments—where the potential for wildlife enjoyment through bird watching is enormous. (340,351)

136. More open space is needed for urban residents, and greater public involvement is needed in urban resource management decisions. Research has found that members of minority groups lack the influence and expertise to participate effectively in resource decisions that affect their well being. Forestry professionals should work actively to increase minority participation in forestry-related issues. (357)

137. Urban planners need to know the economic value of trees on land available for residential development. Professional appraisal of simulated combinations of different amounts and distributions of trees on a 12-acre parcel of land showed that trees can account for as much as 25 percent of the total value. Scattered arrangements of trees were valued more highly than concentrated arrangements. Results strongly suggest that trees should be retained when wooded land is developed for residential use. (322)

138. In order to properly manage a river for recreational activities, it is necessary to understand the conflicts that may arise among various types of recreationists who use the river. For the Au Sable River in Michigan, research has shown that the main causes of conflict among canoeists, fishermen, and other river users, were: 1) Excessive numbers or distributions of users, 2) different objectives among users, and 3) behavior of users. Canoeists, for example, often are not aware of the effect of their presence on fishermen and fish. Management alternatives suggested by various users provide a range of options for river recreation management. (343)

139. New problems have been created by the increased number of people engaged in river recreation. Studies have shown how patterns of river use and characteristics of users vary among rivers, how current users define a high quality river recreation experience, and the kinds of management techniques that will best increase user enjoyment. This information helps scientists focus on future river recreation research efforts and needs. (349)

140. Recreation is too socially important for policy makers and managers to continue to rely primarily on intuition to govern most decisions. For this reason, research has examined why a person participates in a recreational activity, what that person does while participating, and the effects of personal and environmental influences on the recreational behavior. Conceptual models have been developed for defining and measuring recreation demand in behavioral terms. The model presented is applicable nationwide to recreational planning and management. (344)

141. The Forest Service must estimate the demand for and value of outdoor recreation opportunities in the Salt-Verde Basin of Arizona in order to efficiently administer the National Forests in the Basin. A modification of the Clawson—Hotelling approach to estimating recreation demand was employed to generate resource values by both the consumer surplus and nondiscriminating monopolist methods. Higher net values and larger expenditures were associated with sites that: have water-based recreation, considerable development at the sites, and fairly easy access. The nondiscriminating monopolist value for the entire Basin is estimated at $36,376,487 and the consumer surplus value is estimated at $78,438,193. Such values facilitate putting recreation on a comparable basis with other dollar-valued forest outputs. (355)

142. Better information is needed on the goods and services desired from outdoor recreation resources. The psychological basis of outdoor recreation demand is examined and results of selected research on quantifying those demands are interpreted. Results show how recreation demand information can be ob-

tained in a wide range of resource management situations. (342)

143. Public response to resource managers' requests for citizen participation in resource decisionmaking has increased to the point where managers need an objective, systematic procedure for analyzing that input. A specially adapted content-analysis system called *Codinvolve* was developed. The system has been utilized in a variety of land-management issues involving thousands of citizens responses. Four case studies are discussed which demonstrate the flexibility of the system and how it is applied. Problems in applying *Codinvolve* are discussed as well as reactions to it from both managers and the public. This system will aid managers in summarizing large amounts of complex input. (383)

144. Guidelines for campsite spacing and location in roadless areas to achieve certain standards of user isolation are an important management issue in wilderness and backcountry recreation management. Spacing guidelines are given to achieve proposed levels of sound insulation for three kinds of roadless settings based on remoteness—pristine, primitive, and portal—and for meadow, woods, and streamside locations in each. The guidelines were derived from field tests and theory explaining how far noises will carry as affected by environmental factors such as landform barriers, screening, and background noise. These findings now allow managers to determine how many campsites can be allowed and how they might be optimally located in roadless area settings, to achieve three alternative standards of noise insulation. (339)

145. Applied social research can help improve procedures for collecting, analyzing and evaluating public input to resource decisions. Research has indicated that administrators often didn't know about existing social research that has direct implications for their efforts to involve the public. Research has identified some operational problems of administrators in securing public participation in decisionmaking for which applied social research might be helpful. Social researchers are urged to become involved with decisionmakers in public participation projects as a means of identifying how social science concepts and methods might be helpful. (354)

146. Answers are needed concerning effects of recreation on water quality in wildland areas. A study in north central Colorado indicated recreational use alone was not a significant cause of bacterial water pollution. Water pollution appeared to correspond with camper reaction to public opinion and to the type of camper using a campground facility—low density use and corresponding low visibility may encourage some campers to pollute; backpack campers produce less pollution than campers using motorized vehicles. The study suggests the need to prevent vehicular approach to water bodies near campgrounds, to provide adequate toilet facilities, and to better instruct users of motorized campers about proper waste disposal. (337)

147. The rapidly increasing number of vacation homes and recreational developments near National Forests could seriously impact associated water resources. Studies in northern Arizona suggest that dispersed, well-designed, and well-maintained soil disposal systems at suitable locations are well adapted to the forest environment and adequately protect water resources. Conventional sewage treatment systems are not recommended unless unsuitable soil conditions or high density populations preclude the use of soil treatment and individual disposal systems. (352)

ENVIRONMENTAL TREE CULTURE

148. Introduced trees have enriched the environmental quality of communities, recreation areas, and roadsides throughout the world; but these introductions are frequently unsuccessful. A recent report by the Rocky Mountain Forest and Range Experiment Station summarizes information identifying many critical factors such as seed origin, climatic and edaphic conditions, mycorrhizae, insects, disease, and animal factors that affect the health and vigor of introduced species. This summary can serve as a reference guide in making wise species selections of nonlocal trees. (806)

ECOLOGY AND CLASSIFICATION OF NATURAL VEGETATION

149. People interested in trees often do not get the information they want. A popular, but accurate, account of some major tree species has been presented in a widely circulated magazine. This will assist homeowners and others in tree identification. (804)

150. Frost heaving is a leading cause of tree seedling mortality in many parts of the world. Studies in Arizona show that the rate and amount of frost heaving increases with increasing bulk density, that indexes utilizing bulk density and sand content of the soils are useful predictors of frost heaving susceptibility of forest soils, and that measures which lower bulk density, such as plowing or disking, reduce heaving. These results help the forest manager detect where tree regeneration may be adversely affected by frost heaving and offer some possible measures for reducing this damage. (743, 752)

152. Natural areas serve as a base for evaluating silvicultural studies as well as many other functional activities, but the limited representation of many biological and physical phenomena curtail their use to date. A systematic approach has been proposed for building a system of natural areas for Montana. Classification schemes for five natural phenomena groups—forests, grass and shrublands, aquatic, zoologic, and geologic—were developed to serve as a basis for building a complete and representative system of natural areas. This system is used as the guide for natural area work in Montana and could serve as a conceptual framework in other areas as well. (751)

153. Research Natural Areas (RNA's) are essential as sites for basic and applied ecological research, but there has been no master plan for guiding the selection and establishment of new RNA's. A comprehensive plan was developed for a minimal system of RNA's in Oregon and Washington. It includes consideration of the terrestrial, aquatic, and marine ecosystems and rare and endangered species. The plan will facilitate selection and establishment of RNA's without danger of misdirected or overlapping efforts by the many groups involved in this work. (738)

154. A system of classifying forest lands into units of like biological potential, and a better understanding of the ecology of these units, is needed as a basis for research and management in the Rocky Mountains. Classifications for the major forest vegetation types in portions of Wyoming, Idaho, and Montana are now available. These classifications include keys for field identi-

fication, environmental data, vegetation composition, and discussions of land-use implications. These classifications provide new scientific knowledge on forest vegetation and environment as well as a solid ecological foundation for forest management practices. (737,747,755)

155. Effects of seasonal, climatic, and edaphic factors on the frequency and development of mycorrhiza-producing spores are poorly understood. Spore populations and the extent of mycorrhizal infection of wheat roots in Pakistan with fungi of the genus *Endogone* were influenced by soil depth, texture, and water-holding capacity; by pH, organic matter content, and available phosphorus; and by season and the developmental stage of the crop. Knowledge of these relationships may eventually lead to management of these important symbionts for optimum herbaceous and woody plant production. (750,752,785)

IMPROVING ENVIRONMENTAL QUALITY THROUGH FIRE MANAGEMENT

Fire prevention, hazard reduction, and prescribed burning

156. Techniques for spraying chemicals on small test plots must produce a uniform and reproducible spray pattern that simulates the treatments of large-scale operational spray-jobs. Specially designed equipment is required for controlled herbicide applications over tall brush. A tripod-supported pneumatic pressurized boom sprayer was developed and has been used on shrubby vegetation on hundreds of plots. The volume of spray applied per acre can be readily changed. The sprayer will be of interest to researchers everywhere who have responsibility for applying herbicides to tall brush. (678)

157. Because of high fire danger in California, it is important to identify high fire-risk forest using publics. In this study, age, sex, education, and income were most closely related to variations in knowledge of and attitudes about fire, fire behavior, and forest activity. Youths and persons 65 years old or older who have limited education and income were identified as high risks. For increased prevention effectiveness, fire prevention administrators in northern California should design programs with this group in mind. (677)

158. Forest residues in the Pacific Northwest usually require treatment to meet land management objectives. Over 200 guideline statements were developed by experts in various land management disciplines to help land managers apply technical and research knowledge in achieving these objectives. A unique keying system is provided for determining which guidelines apply to each planned management activity on a given site within a given forest species association type. Application of these guidelines can materially improve the quality of residue management on both public and private forest lands. (683)

159. Forest residues are a fire hazard, an obstacle to regeneration, and, in some instances, wasteful. Dragging a high-lead scarification device through cutover areas was found to be a suitable treatment for small diameter residue or brush; burying was determined to be feasible in special situations, such as roadside cleanup or recreation area development. However, efforts to speed decomposition by applying chemicals have been disappointing. On the utilization side, less residue was found following the sale of small, low grade material on a per-acre lump-sum basis than when the sale was on a scale basis. Incorporating this information into land management planning will help assure the soundness of decisions. (679,685,687,688,689)

160. Increased use of prescribed burning could be facilitated in areas with fragile soil or high fire hazard if the need and costs for building standard control lines could be reduced. A survey of fire management specialists of National Forest Regions indicated a semi-permanent fire retardant would have potential in prescribed burning and along high-use roads in critical fire hazard areas. The findings suggest that an attempt should be made to develop an economical semipermanent retardant. (681)

161. The effect of heat from prescribed fire upon seed germination is not well understood. Seed from several leguminous species that are important sources of quail food were laboratory tested for heat response. In about half of the species, germination was increased by moist heat—the type produced by a forest fire. The seed coat appeared to be the factor responsible for excluding water and maintaining dormancy in the other species tested. Future research should reveal the field conditions under which a fire produces heat and moisture that are optimum for germination. (680)

162. Knowing the personal characteristics of effective fire prevention contractors would assist in hiring and placing personnel in these jobs. A study of prevention personnel in the North Carolina Forest Service indicated that effectiveness was positively related to ability to communicate, acceptance of self and others, achievement orientation, and motivation toward self-improvement. The North Carolina Forest Service was provided a simple test for measuring these attributes in potential employees. (675)

163. Unsuccessful fire prevention efforts often are based upon insufficient information about the fire-setters they are directed against. This study found that persons who had started fires deliberately usually were indigenous, young, married, white males with some high school education and poor financial records but no criminal record. Persons who had started fires accidentally generally were older and less educated than the incendiarists, but otherwise quite similar to them. This study is a requisite step in the process of developing guidelines for evaluating man-caused fire problems for prevention planning purposes. (676)

164. In order to be of optimum benefit, the findings of individual fire prevention studies must be synthesized, interpreted, and used as a basis for recommending action. Ten years of sociological analysis of the South's incendiary fire problem clearly establishes the deep roots of the practice in certain rural sub-cultures. This fact suggests that a significant and lasting change of the picture could be effected by a program directed toward the source of the problem; a community development approach is recommended as such a program. This information will be used in conducting and evaluating an experimental development program in an area of high incendiarism. (672)

165. A relationship between the amount of duff burned in prescribed fires and the overall heat release (or intensity) involved in the surface fire has been presumed more or less explicitly in the fire research community. A detailed review of data gathered during a series of prescribed slash fires was undertaken in an effort to quantify such a relationship. The failure to discover any such relationship implies a much weaker connection

between these measures of fire behavior and effects than often has been presumed. Further research is recommended. (669)

166. Prescribed broadcast burns in the intermountain West do not always meet desired objectives; erratic results often are produced. An equation has been devised for predicting duff depth reduction from upper duff moisture content and buildup index. Total fuel reduction can be estimated using the same variables along with preburn weight of 1-10cm fuels. A fire manager can greatly increase the probability of a successful burn by considering these results. (671)

167. Mesofauna of the forest floor benefit tree growth indirectly by their involvement in organic matter decomposition, yet the effects of cultural practices on the fauna are not well understood. In a study in South Carolina, the population of *Collembola* decreased with annual burning, but not with burning every 5-8 years. Prescribed burning (both annual and periodic) increased the species diversity of *Collembola*. Because complexity insures stability within ecological systems, cultural practices that simplify forest ecosystems should be used cautiously. (725,728,729)

Fire management methods and systems

168. Damage resulting from a forest fire is little understood, highly complex, and inconsistently evaluated between various agencies. The need for a standard fire damage appraisal system on all federal lands was illustrated by applying two agencies' appraisal criteria to one fire with considerable differences resulting. Forest fire control agencies must use proximate criteria for damage appraisal until research in economics-based evaluation can be completed. (706)

169. Until 1972, fire location information on the Forest Service's Individual Fire Reports was not suitable for quantitative analysis. A computer-based technique called the Regional Area Mapping Procedure (RAMP) was developed which converts locations expressed in section-range-township notations into latitude-longitude coordinates. Not only does RAMP allow retrieval of important historical fire data, but the technique can be applied to other types of land-management problems. (705)

170. Transmission of infrared imagery from a fire-mapping aircraft to a fire camp has always required physical transfer. Now a telemetry technique has been developed which allows transmitting infrared imagery from an aircraft to the fire camp in near real-time. This technique offers an effective means of providing the fire boss with accurate, up-to-the-minute information about the fire. (710)

171. Fire planners need to know where to obtain fire weather information, and they need seasonal guides for proper allocation of firefighting resources—regionally and interregionally. A map showing the location of all fire weather stations in the northeastern and northcentral United States now is available, and the average dates of greening and curing of herbaceous plants, annual profiles of peak fire activity, median size of fires in various fuels, and other measures of fire activity have been documented. This kind of information allows fire planners to set objective limits on fire season and to compare actual fire occurrence with that predicted by fire danger rating systems. (693,698,699)

172. With the cost of direct suppression increasing at an alarming rate, alternatives such as fuels management must be seriously explored. Research in the northeastern United States indicates that establishment of hardwood fuel breaks using endemic species is a promising fuels-management practice. A study in Missouri established the lower and upper limits of organic matter on the forest floor under a 40-year old, fully stocked oak stand. Other research indicates that the amount of slash fuel present after cutting Northern Red Oak (*Quercus rubra* L.) can be predicted using diameter at the base of the crown. Either used directly or as input into the National Fire Danger Rating System, this kind of information enables fire managers to evaluate their alternatives in a more objective manner than before. (701,702,703)

173. Fire managers find it difficult to keep abreast of the advances in fire management research and technology. A guide for using fire retarding chemicals in ground tankers provides fire managers in the South with current basics on storing, mixing, and applying retardants and encourages their on-the-ground trial and use. Fire managers everywhere should find this guide useful, both as a general reference and as a how-to-do-it booklet. (704)

174. For reasons of economy, it may be necessary to close one or several fire-weather stations in a protection area. Since it is logical to close those stations that will have the least impact on the ability of the fire manager to assess overall fire danger, it is desirable to know if there is duplication in monitoring fire climate, and to what degree. A method is proposed for determining this duplication based on an analysis of six elements of fire climate. Stations are grouped on the basis of similarity of sequences of these fire climate elements over the fire season. Such information, used in conjunction with other considerations, may be useful in streamlining fire weather monitoring networks. (694)

175. Planning fire suppression activities requires good, up-to-date accessible weather data. The National Fire Weather Data library is a collection of daily observations from fire weather stations across the United States. Current data are accumulated on collection tapes, then merged onto library tapes annually. The data library is accessible to all users of the USDA computer in Fort Collins, Colorado. (695)

176. The National Fire Danger Rating System is used nationally for assessing fire danger. Procedures for processing fire danger data utilizing a time-share computer via a remote terminal are presented in non-technical language in a recent guide. Input includes fuels and weather information; output includes narrative messages sent from other users, displays of observed and forecasted weather, and fire danger indexes. Observed fuels and weather data are automatically checked for errors and archived. The guide should be indispensable to users of the system. (700)

177. Application of fire retardant chemicals to forest fires has been hindered by lack of definitive criteria for specifying the amount of retardant needed based on the fuel situation. This study developed a method of determining the maximum useful retardant concentration from a knowledge of the fuel load, the size class distribution of the particles, and the chemical makeup of the fuel. The results have been applied to the nine standard fuel models of the National Fire-Danger Rating System and incorporated into the Operational Guidelines for Retardant Tankers. (707)

178. The National Fire-Danger Rating System (NFDRS) needs to be tied closely to local fuels so fire-danger evaluations can be more specific. Fuel models were developed to provide the

data needed in mathematical fire behavior modeling of the spread and energy release components of the NFDRS. The fuel models quantitatively describe those physical and chemical properties of fuel elements and fuel beds that govern flammability. Nine models currently describe broad vegetative types for rating fire danger and can be refined to give greater coverage and incorporate dynamic features such as seasonal variations in fuel properties. More skillful interpretation and application of the information provided by the NFDRS will result. (692)

179. To obtain maximum efficiency of aerially delivered fire retardant, fire control personnel must know and understand the performance of the delivery systems they are using. A method for determining air tanker performance through static testing and a basic format for user guides has been developed to allow more flexible and efficient use of air tankers. The performance guides provide fire management a means for evaluating air tanker operations, comparing different tankers, and assessing the value of specific drops. (708,696)

180. Use of the Canadair CL-215 air tanker by fire suppression agencies has been proposed. Using data collected in drop tests, mathematical models for several retardants and load sizes were developed for predicting the effects of drop height on ground distribution. Retardant drop efficiency and safety can be improved by the use of gum-thickened retardants. This information will be valuable to fire suppression agencies in deciding upon use of the CL-215. (697)

181. Although the term "fire management" is increasingly used today, its origin and meaning remain unclear. A perspective and definition of the term is offered in a recent article in an effort to improve communication and understanding. (690)

182. The basic knowledge to return fire to wilderness is available, but the land manager must proceed very carefully. A study in the Selway-Bitterroot Wilderness Area of Idaho has helped develop procedures for allowing fires to play a more natural role in wilderness. Such wilderness-oriented research can assist forest managers inside and outside wilderness areas. (724)

Forest fire science

183. Basic knowledge of fire behavior concepts and the ability to apply these concepts to wildland fire problems should be a part of the skills of all fire control personnel. This publication describes the characteristics of heat that are basic to the understanding of heat transfer in wildland fire. This understanding will enable fire control personnel to do their job more effectively and more safely. (714)

184. Fire managers lack adequate knowledge of the behavior of large fires including mass fires and conflagrations. In a series of experimental free-burning fires, the rate of rise of the convection column depended upon the atmospheric lapse rate in the lower 1000 meters. For the fuel used in these tests—a mixture of Pinyon pine and Utah juniper—the size of a mass fire was defined as 27 ± 2 hectares. These data contribute to the development of theoretical mass fire models. (718)

185. Temperature, wind velocity and direction can vary drastically before, during, and after wild or prescribed fires. A data-recording system based on the logarithmic character of semiconductors has been developed for observing turbulent fluctuations from the mean in ratio form. The system combines a recorder, discriminator, amplifier, thermocouple, and anemometer. It has been satisfactorily field tested under severe ambient and fire conditions, providing useful fire research data. This system also can be used to record and determine mixing ratios in turbulent areas, providing information needed for air-quality studies. (717)

186. The pocosin shrubs of the eastern North Carolina organic soils area become a severe fire hazard during low points in their annual moisture cycle. Observation of seasonal variation in moisture content of six species of shrubs over two growing seasons revealed an annual pattern of variation for each species. North-south location and proximity to the seacoast had a strong influence on the timing of the annual cycles, and early spring, just before growth began, was the time of lowest moisture content. These results can aid fire suppression forces in preparing for expected severe fire situations. (713)

187. Field experiments of prescribed burning often require measurement of smoke plume volume flow. A method of simultaneous motion picture photography was developed and tested using triangulation from two camera positions. Measurement of coordinate data was made using two stop-frame film projectors mounted beneath a frosted glass viewing table. This inexpensive and accurate method appears adequate for most applications on field experiments of prescribed burning. (719)

188. Prediction of fire danger by the National Fire Danger Rating (NFDR) System requires precise knowledge of moisture content of fuels which, in turn, demands knowledge of the relationship between environmental parameters and the transport of water liquid and vapor into the fuels. Two models have been developed—one for conifer forest litter and duff and one for heavy forest fuels. These models facilitate the estimation of moisture content and, therefore, can be used by the NFDR System. (715,716)

189. In gathering data on fuel loadings, size class distributions, and fuel bed depths for purposes of assessing potential fire behavior, disparate fuel communities frequently are sampled and the data are intermingled. An algorithm has been developed which permits automated partitioning of such data into groups of samples which have similar fuel bed depths. Copies of the computer program are available; use of this method will improve predictions of fire behavior. (711)

190. Proper management of lodgepole pine requires full awareness of the biological effects of fire. The accumulation of ground fuels and related fire intensity potential seems to follow two consistencies: (1) Fuel quantities and fire potential become predictably high as stands reach overmaturity; and (2) fuel quantities and fire potential in young and immature stands cannot be predicted from age alone. A summary paper provides a clearer understanding of the intricate relationships between fuel, fire, and lodgepole pine and will aid fire management in this type. (723,727)

191. Ignition temperatures of fine forest fuels must be known if the rate of fire spread is to be accurately predicted. Spontaneous and pilot ignition tests on the needles of ponderosa pine (*Pinus ponderosa* Laws.) showed that piloted ignition occurred at lower flux intensities and in less time than did spontaneous ignition. A significant difference in delay time to ignition was found for sample moisture contents above 7.7 percent. This information is useful input for rate-of-spread models. (721)

192. The type and extent of land uses and management on municipal watersheds are interrelated with water supply problems. A survey of land uses permitted in municipal watersheds

in the eastern United States was summarized. The survey determined the nature of land-management problems and information, research, and practices needed to improve water supplies from municipal watersheds. This information was needed to formulate research and management programs for eastern watersheds. (66,67)

IMPROVING INSECT AND DISEASE CONTROL

Detection and evaluation

193. Wood deterioration in single-family frame houses along the Gulf Coast is extensive and costly for homeowners. A recent survey of homeowners revealed that moisture/decay damage to such houses has been more frequent than termite damage in recent years. Definition of problems occurring in these houses has provided performance aids for building inspectors, architects, and agencies preparing national building codes, and it has indicated need for changes in building designs to reduce damage. (532,533)

194. Cottonwood is damaged by a number of insects and diseases. A recent publication with numerous illustrations describes 10 important insects and eight important diseases of cottonwood. This information will aid foresters and land managers in recognizing major insects and diseases and in selecting means to reduce the damage they cause. (539)

195. Sycamores in some commercial plantings in the South have been killed by diseases; however, the extent of this mortality was unknown. A recent survey revealed that losses averaged less than 5 percent in 26 plantations. This information has prompted forest industries to renew or increase the planting of sycamore. (535)

196. To improve habitats for migrating waterfowl, southern forest landowners from the Mississippi to the Atlantic flyway are increasingly building green tree reservoirs which involve temporary impounding of water. The effects temporary impoundments have on mycorrhizae and other soil microflora in southern hardwoods were evaluated; mycorrhizal species were not eliminated but populations were reduced. No damage to trees was detected. This information can be used by foresters to insure landowners that green-tree reservoirs are not likely to reduce timber production. (534)

197. Fusiform rust is recognized as the most damaging disease of forest trees in the South, but little information has been published relating incidence rates to financial impact of the disease. Data from the forest survey have been expanded to estimate financial impact of fusiform rust southwide. This information will be of value to forest managers in the South. (541)

198. Aerial photography can be used to detect, evaluate, and follow tree disease progression; however, this method is useful only with certain types of diseases. Diseases for which this method has been effectively used have been listed and discussion presented on the newer possibilities of large-scale detection of tree diseases by remote sensing techniques. (537)

199. Better methods are needed for detection of decay in tree roots. The pattern of electrical resistance measurements was used to detect decay associated with *Fomes annosus* in red pine. The method shows great promise for accurate detection of root decays in trees. (542)

200. In trees with high-unit values, the ability to detect defect within the bole is very important. Tests on black walnut demonstrated that discolored and decayed wood in living trees could be detected using a pulsed electric current. Further refinement and application of this technique will improve management and utilization of this valuable species. (538)

201. The spruce budworm represents a potential threat to nurseries and shelterbelts of the Northern Plains, and a better system is needed to survey for its presence. Traps baited with the pheromone *trans*-11-tetradecenal were placed in 13 shelterbelt and nursery plantings in North Dakota. Moths were captured at 12 of the 13 locations. The sex attractant may prove very useful in (a) detecting populations of this insect pest in nurseries, shelterbelts, and similar plantings in the northern plains and (b) preventing spread of the budworm with movement of infested nursery stock. (372)

202. More effective sampling methods are needed to evaluate the spring cankerworm, a severe defoliator of Siberian elm in the northern Great Plains shelterbelts. Individual trees were sprayed with a pyrethrum insecticide applied by a backpack mist blower, a rapid, nondestructive technique that provides a whole-tree count of cankerworm larvae. This efficient sampling technique has no adverse environmental effects and is applicable for sampling a variety of insects on most trees under intensive culture. (371)

203. Trees and shrubs are valuable components of urban areas on the Great Plains, yet, homeowners often have no knowledge of how to obtain reliable advice on identifying damaging insects or how to control them. This report summarizes basic requirements for proper collection, preservation, and shipment by homeowners for obtaining identifications from their State extension entomologists. A reference table also lists 184 typical or prevalent insects associated with 52 trees and shrubs found in North and South Dakota. With these guidelines, homeowners can make the best use of entomological services available to them, and assist entomologists in becoming aware of local insect problems. (370)

204. The European pine sawfly damages Scotch and red pine plantations, and we need improved sampling methods to improve surveys and damage prediction for this pest. The egg clusters are reliable for sampling population levels, and the distribution patterns of egg clusters are useful in devising sampling schemes. This sawfly has a strong edge effect so that twice as many eggs are found on edge rows and around openings. Eggs were distributed in an overdispersed manner with an index of 1.49 by Taylor's Power Law. We now have a practical sampling method for assessing the numbers and distribution of sawfly eggs in plantations, and this information, in turn, will improve our pest management decisionmaking process. (375)

205. The pine root collar weevil, a pest of red pine plantations, is difficult to sample because of its cryptic habits. Larvae are the most reliable sampling units, but the trees must be sacrificed in sampling because the larvae feed inside the tissues. Egg sampling also yields reasonable population parameters, however, and 93 percent of the eggs can be recovered in the outer bark and soil within 3 cm of the root collar. Distribution of eggs within plantations revealed an overdispersion index of 1.25 (Taylor's Power Law) which indicates they are not strongly aggregated.

With this information, we can now develop a practical egg sampling method that can be used to assess weevil populations and predict potential weevil damage to red pine plantations. (374)

206. Although the white pine weevil is a major pest of coniferous trees in the northeastern United States, we lack sufficient understanding of its biology and population dynamics to develop satisfactory methods of minimizing its damage. A key factor in any control program is a rapid, accurate sampling technique to estimate pest populations. A nondestructive photographic technique for estimating egg density correlates well with the standard time-consuming and destructive technique involving microscopic examination and/or dissection of individual leaders. At least on leaders with low needle density, we now have a rapid, nondestructive method of sampling eggs and thereby projecting adult populations. (378)

207. We need to know the seasonal flight periods of moths attacking seed orchards before we can effectively apply insecticidal controls. Light traps were used to trap and sample species of seed- and cone-infesting moths. With this information, the emergence periods, generations per year, and relative abundance of species were determined. Seed orchard managers can now schedule effective applications of insecticides to control the major seed- and cone-infesting moths. (376,377)

208. Identifying damaging insects and developing methods to evaluate impacts of insect activity are major problems in southern pine seed orchards. Major pest species have now been associated with particular geographic locations, and host age, and seed source. An illustrated key to the identity of a group of cone midges has been devised. Improved sampling methods are being developed for five pine species in seven southern States to enhance our capability to evaluate the efficacy of insect control measures. This information will substantially improve the ability of seed orchard managers to evaluate and employ a number of management strategies to minimize insect losses in seed orchards. (364,365,366,369)

209. More information is needed on the identification of insect pests and their damage in southern pine cone and seed orchards. Keys are now available to identify specific insect pests such as seed worms, flower thrips, seed bugs, and midges. Seed and cone losses directly attributable to insects with and without control attempts have been documented. We now have the basic information necessary to determine research priorities, damage assessments, and control strategies for seed- and cone-damaging insects. (358,359,362,363)

210. Thousands of acres of ohia and ohia-koa rain forests on the island of Hawaii are being decimated by some undetermined factor. Interpretation of aerial photographs taken from 1954 to 1972 shows a drastic decrease in the acreage of healthy forests and a manyfold increase in acreage of forests with severe decline symptoms. This information regarding location, extent, and rate of spread of the decline will help guide management of these important forests. (540)

211. Insects can reduce growth and impair the form of black walnut trees, particularly those trees 3 to 8 years old and being managed for future timber production. In 1974, 62 insect species were found feeding on black walnut trees in Missouri. Bud and shoot insects, which cause loss of terminal dominance, are the most destructive and important. Preventive and corrective measures are needed to reduce the damage. (367)

212. Some measure of the damage caused by tip moths would be useful in selecting pines for afforesting the sandhills. Plantings of loblolly, shortleaf, and Choctawhatchee sand pine chemically treated annually to prevent tip moth damage were compared with untreated plantings at age 10 years. Untreated plantings averaged shorter and smaller in diameter than treated plantings. Differences between plantings were greatest for loblolly and least for sand pine. Untreated sand pines were taller and larger than treated loblolly and shortleaf pines. Results clearly recommend Choctawhatchee sand pine as a likely choice for afforesting sandhill land within its projected range. (361)

Biology and understanding

213. Chromatographic identification and quantification of plant sugars are often erroneous because of an inability to isolate constituent sugars on chromatographic media. By testing different combinations of solvents and media, thin-layer-chromatography techniques were developed which permit accurate identification and reproducible quantification of sugars in plant extracts. These techniques will be useful to scientists studying physiological changes in plants, particularly changes in sugars caused by disease and insect attack. (585)

214. Information on changes in kinds and quantities of sugars in woody plant tissues when infected by obligate parasites, like the white pine blister rust fungus, is very limited. No qualitative changes in sugars were found between *Pinus monticola* bark infected and noninfected with this fungus; however, there were significantly less glucose, sucrose, raffinose, and total sugars in infected bark tissues. This information will be of value to scientists investigating host-parasite relationships. (632)

215. Host-pathogen interactions at the host cell wall and hyphal cell wall interface are unknown for *Pinus monticola* and the white pine blister rust fungus, *Cronartium ribicola*. Observations of infected bark tissues with light and electron microscopes revealed that hyphae of this fungus are firmly affixed to pine cell walls and covered with a layer of an electron dense, extracellular, gel-like material. Strands of this gel-like material may connect several rust hyphae not otherwise in contact and may bridge spaces between pine cells and unaffixed hyphal cells. Host-parasite interactions are shown for the first time to involve a gel-like material that appears to have an adhesive function. This information adds to our basic knowledge of host-parasite relationships and will benefit scientists investigating such relationships. (633)

216. Investigations to develop genetic resistance to the white pine blister rust fungus in *Pinus monticola* would be simplified by the existence of markers of specific host-parasite combinations. Two kinds of needle spots, red and yellow, were found 9 months after inoculation of nursery grown seedlings with field-run *Cronartium ribicola* inoculum. An analysis of needle-spot types and frequencies indicated that the field-run inoculum was composed of at least two races and that the pine seedlings exhibited differential resistance to those races. The real significance of these findings resides in the possibility of using the races, if they exist, as markers in many kinds of genetic studies of *C. ribicola* and its hosts. (588)

217. A mechanism of resistance to *Cronartium ribicola*, not previously observed in white pines, was found in *Pinus armandii* needles infected by this rust fungus. This mechanism is a hypersensitive reaction which we now can recognize, thus we

can probably find it in *Pinus monticola* and therefore increase its frequency and importance in this species. (568)

218. Knowledge of the extent of pathogenic variation in *Cronartium fusiforme* has been very meager although such information is basic to breeding trees for resistance to this rust fungus. To determine the extent of pathogenic variation in *C. fusiforme*, several slash pine families were exposed to inocula from diverse locations in the South. Although two families were resistant to inocula from five States, most families responded variably to inocula from widely separated locations as well as from individual rust galls within locations. These findings demonstrate much genetic diversity in both the fungus and host populations. The concepts developed will lead to greater efficiency and reliability in resistance breeding programs. (551,624)

219. The lack of an efficient method for inoculating pines with *Scirrhia acicola* has hindered research on the brown spot needle blight disease of longleaf pine. Conditions of light, high humidity, and temperature which favor infection of inoculated seedlings were determined. Thus a new inoculation technique has been developed which can be used to screen pines for resistance to the brown spot fungus. (572)

220. The ability of some decay fungi to attack wood is influenced by light, but it was not known whether light affected the specific assay organisms used in standardized tests of efficacy of wood preservatives against fungi or in tests of wood resistance to decay-fungi. Specific assay organisms that are affected by variations in wave length were distinguished from those that are not. This knowledge can be used to improve the reliability of standard laboratory soil-block wood decay tests. (550)

221. *Endothia gyrosa* causes a canker disease on several species of deciduous trees. Recent studies in the Southern United States indicate this fungus can cause serious cankering on *Liquidambar formosana* and suggests the possibility of an epidemic in Asia reciprocal to chestnut blight in the U.S. Care should be taken to assure that this strain of the pathogen is not introduced into the range of *L. formosana* in Asia. (622)

222. Black stain root disease causes considerable mortality to pines, true fir, and Douglas-fir in Western North America. Information on hosts, distribution, symptoms, disease cycle, damage, and control has been presented in leaflet form. This information will be of value to those interested in reducing damage caused by this disease. (621)

223. True firs in the Western United States can be severely damaged by the canker fungus, *Cytospora abietis*. The biology, symptoms, and damage caused by this fungus have been presented in leaflet form along with suggestions for control. This information will be of value to those who are interested in reducing the damage caused by this fungus. (604)

224. Littleleaf disease of shortleaf and loblolly pines has been attributed to *Phytophthora cinnamomi* on severely eroded, clay sites; however, other root infecting fungi may be involved. Close association of *Pythium* species with *Phytophthora cinnamomi* on sites with littleleaf diseased trees was shown for the first time. This information will be of value of pathologists who are seeking to more fully understand this disease so that losses may be reduced. (599)

225. Any possible role of mycorrhizae as biological deterrents to feeder root diseases of plants has been unknown. Most work has shown that ectomycorrhizae function not only as mechanical barriers to infection by pathogenic fungi but also as chemical barriers. Many ectomycorrhizal fungi have been found to produce antibiotics ideally located in mycorrhizae to deter infection by pathogens. Further studies will be needed to fully elucidate the role of mycorrhizae in limiting root diseases. (586)

226. Plant-parasitic nematodes have been associated with shortleaf pine exhibiting symptoms of littleleaf disease; but information on which nematodes parasitized feeder roots was unknown. In a greenhouse study, two nematode species, *Hoplolaimus galeatus* and *Meloidodera floridensis*, parasitized pine seedling roots and caused measurable root damage; thus these nematodes must be classified as pathogens of shortleaf pine. (603)

227. The Peruvian Government and other groups are interested in the potential pine afforestation of the grass plains of the high Andes in Peru. Since pine need ectomycorrhizae to survive and grow normally, a mycorrhizal survey was made on the scattered planted *Pinus* and *Eucalyptus* in the Andes of Peru. Only a few ectomycorrhizal fungi were observed, which suggests that pure culture introduction of specific mycorrhizal fungi may be desirable. Since Mexican pines are the desired pine species for the Andes, a mycorrhizal synthesis experiment was conducted with them: *Pisolithus*, *Thelephora*, and *Cenococcum* formed beneficial ectomycorrhizae on them and, therefore, are potentially useful in pine afforestation in the Andes. (587)

228. Spread of *Poria weirii* in stands established in cutover infested sites might be reduced by interplanting species resistant to this fungus. Red alder is a promising candidate for interplanting or crop rotation. Cubes of Douglas-fir wood decayed by *P. weirii* were buried for 12 months in paired plots in red alder soils and in conifer soils; however, survival of the fungus did not differ in the two soils. (593)

229. Information on rate of spread of the root disease fungus, *Poria weirii*, in the Pacific Northwest is needed to improve timber management and recreation decisions. By measuring 10 centers on 1946 aerial photographs and again on 1972 photos, progress of the disease in a given direction was estimated. Thus, in mixed, high-elevation forests of the Oregon Cascade Mountains, foresters can now base their management decisions on projected root disease losses. (592)

230. *Poria weirii* normally survives for many years in buried wood, causing reinfection of stands developing on infested sites. When urea was incorporated in soil around buried cubes colonized by the fungus or broadcast on the soil surface, survival was reduced from 31 percent to 0 and from 48 to 2 percent, respectively. If urea can similarly reduce survival of the fungus in colonized roots of stumps and dead trees, it could provide effective control of *P. weirii* on harvested forest lands. (590)

231. The mechanism of reducing *P. weirii* survival in buried wood by application of a given level of nitrogen is not known. Alder stem sections colonized by *P. weirii* were buried in soil and incubated at 15°C. over a period of 32 weeks. Fungus survival lessened with time. The larger the N application, the greater was its effect on survival. Populations of *Trichoderma* were associated with decline in survival. Stimulation of *Trichoderma* by levels of urea used here might also be effectively used to reduce survival of *P. weirii* in nature. (591)

232. *Phellinus* (*Poria*) *weirii*, occurring over a wide variety of forest types and sites, varies considerably in appearance and in physiological characteristics. Growth of high and low elevation

isolates was not different between 5° and 30°C. nor was survival between −20°C. and 34°C. Thus, much of our knowledge of low-elevation *P. weirii* accumulated over the past 30 years probably applies to high-elevation *P. weirii* as well. (594)

233. Proposed methods for controlling *Phellinus* (*Poria*) *weirii* root rot cannot be quickly assessed in field studies because the fungus cannot be isolated from soil or root surfaces. Thus, its response to a control treatment can be evaluated only indirectly and often only after many years. Now the nutritional requirements of this fungus have been determined, and it can be grown more easily in culture. This knowledge will be helpful in improving the efficiency of research on control methods. (583)

234. Red alder has potential for biological control of *Phellinus* (*Poria*) *weirii* root rot in the Douglas-fir region, since it resists the disease and changes soil properties to the detriment of the fungus. However, young (10–17-year-old) Douglas-fir plantations which contain naturally regenerated alders of the same age have as high an incidence of the root rot as plantations where alders are absent. Clearly, alder needs more lead time to diminish the pathogen's infective population. (562)

235. Research on mycorrhizae that are vital to survival and growth of trees has been impeded by an inadequate system for classifying and identifying the fungi involved. Significant progress in classifying these important fungi is represented by recent monographs of one entire family and three additional genera of hypogeous, mycorrhizal fungi. Numerous related classification questions have been resolved, so that these fungi can now be incorporated into research on mycorrhizae. This is a vital step towards developing methods to manage mycorrhizae for increasing tree survival and yield. (625,626,627,628,629,630,631)

236. Insects that feed on fungi are primary dispersal agents for many beneficial and pathogenic species of fungi. A bibliography listing nearly 300 articles relating to this subject has been published. From information in these articles, listings have been made of beetles associated with fruiting bodies of mycorrhizal fungi. This information will be helpful to those engaged in insect-fungus related research. (552,553)

237. Some tree species do not absorb nitrate nitrogen effectively; however, certain mycorrhizal fungi symbiotic with tree roots can reduce nitrates to forms readily absorbed. A recent experiment indicated that two vesicular-arbuscular mycorrhizal fungi can reduce nitrates. Thus, it is likely that trees having these fungi associated with their roots could effectively compete for nitrates in soil even though they could not absorb nitrates. (566)

238. The taxonomy of mycorrhizal fungi is difficult for most mycologists. The presence of an active acid phosphatase in cultures of six ectomycorrhizal fungi was detected after incubation with Disodium p-nitrophenyl phosphate. In a subsequent starch gel electrophoretic analysis, three of these species produced a fast intense reaction in the developing solution and the other three reacted slowly with a weak, blurred spot. Fungal taxonomists now have another factor to use in differentiating between these species. (567)

239. Little is known about the kinds and extent of injury caused by nematodes in Pacific Northwestern forests. A nematode species previously reported to infest mycorrhizae of Douglas-fir has been discovered on mycorrhizae of western hemlock and Sitka spruce. With this information, forest pathologists will be better able to keep watch for damage caused by this nematode. (635)

240. Before we can manage populations of gypsy moths, we must understand the mechanisms by which innocuous populations dramatically increase to damaging levels. In low populations, egg-mass density was 10 times higher along the forest edge than within the forest. Half the egg masses found at low densities were deposited on man-made objects—litter. Thus, littering the forest edge could contribute to the likelihood of future gypsy moth outbreaks. (395)

241. A number of tree diseases previously thought to be caused by viruses now are known to be caused by mycoplasmas. A recent review of these diseases lists mycoplasma-associated diseases of trees and discusses symptoms. This information will be helpful in disease identification. (634)

242. A serious problem of the eastern deciduous forests in recent years has been the dieback and decline diseases of important tree species. Both drought and defoliation have been associated with these diseases. The combined effects of drought and defoliation resulted in lower levels of starch in roots of black oak seedlings than either drought or defoliation alone. This information indicates that stress prior to or in combination with defoliation could result in greater tree damage because of greater depletion of food (starch) reserves. This information will be useful to pathologists investigating dieback and decline diseases. (602)

243. Knowledge of the location of food reserves (starch) in roots of deciduous trees is needed for investigations of dieback and decline diseases in eastern forests. The major portion of starch in roots of sugar maple was found to be stored in the xylem and ray parenchyma cells. This information will be useful to research foresters and others engaged in disease research. (600)

244. Survival mechanisms in trees subjected to defoliation are poorly understood. From a study of the magnitude of photosynthesis in *Quercus velutina* under various conditions, it is concluded that photosynthesis in twig bark may be important in enabling a tree to survive loss of foliage. Plant physiologists and others will use this information as a basis for further investigations. (601)

245. Surveys of previously affected beech stands indicate that both agents of beech bark disease (the scale, *Cryptococcus fagi*, and the fungus, *Nectria coccinea* var. *faginata*) are now endemic. Regeneration (via root sprouts) of killed beech has created highly susceptible beech thickets, thus setting the stage for a recurrence of heavy beech mortality over wide areas. (571)

246. Better methods are needed for non-destructive determination of physiological processes of disease that precede symptom expression. One method was developed as a result of testing the hypothesis that disease resistance is related to vigor, and vigor is related to cambial ion concentration. The technique involves measuring cambial electrical resistance. Researchers will find this technique useful in further studies involving disease development in trees. (616)

247. It is not clear what happens as root decay spreads from the roots to the trunk of a tree. Dissections and studies of red pine infected with *Fomes annosus* showed that the decay was compartmentalized in the trunk. The diameter of the trunk at the time the fungus moved from the roots to the trunk was the diameter of the trunk decay column. An understanding of com-

partmentalization of root decay in the trunk is essential to understanding the development of the root problem. (608)

248. The factors that initiate heartwood formation in trees are poorly understood. Results of research indicate that wounds stalled the formation of heartwood in white oaks in Maine and Missouri. This information will be valuable to those interested in high value heartwood in many species of trees. (589)

249. Better methods for controlling tree decay depend on a better understanding of it. An expanded concept of decay has been developed which includes host response to wounding and successions of microorganisms. Compartmentalization of decay is an important part of host response mechanisms. Trees repair injured tissues by compartmentalizing them. An understanding of compartmentalization will help us develop more effective methods for controlling decay. (609,610)

250. Great confusion still exists regarding differences between heartwood and discolored wood in trees. Investigations have shown that discolored wood results from injuries, while heartwood results from normal aging processes. Knowing the difference between these two processes can help the tree manager make decisions on the value of wood in trees. This information should be of benefit to all tree managers, especially those interested in high-quality wood products. (611,612)

251. Wounds are the number one problem of city trees. These wounds start the processes that lead to decay. Information on wounds and the processes leading to decay have been summarized. Through a greater awareness of these processes, better methods for detection and prevention of decay can be accomplished. The fact that commonly-used wound dressings do not stop tree decay is of particular interest. (613,614,617)

252. The beech bark disease is well established in the Eastern United States and is spreading. A detailed account of this disease has been prepared for use by tree managers in developing more effective plans for combating the disease. (615,618)

253. Resistant clones of aspen provide the most likely method of reducing losses to *Hypoxylon* canker, but knowledge of the variability present in the pathogen must be obtained to help guide development of screening procedures for selecting resistant aspens. *Hypoxylon mammatum* was found to possess a large amount of variability in nature; thus screening for resistance must be done with a large number of biotypes of the pathogen obtained throughout the region where candidate clones will be used. (547)

254. Land managers in the North Central States are concerned with *Hypoxylon* canker of aspen, and often request details for identifying the disease and guidelines for managing the aspen resource to minimize losses. A brochure has been prepared which illustrates in color photos and text the symptoms for identifying *Hypoxylon* canker of aspen and gives management guidelines for reducing the impact of this disease. (606)

255. Hypoxylon canker is a serious disease of quaking aspen and is present throughout most of the range of aspen. Investigations of this disease have been hampered because of a lack of information on how infection occurs under natural conditions. In recent investigations, four-fold more peroxidase was present around newly infected wounds than around noninfected wounds. More importantly, an inhibition of the wound-healing response in the bark is one of the first events that occurs when aspen becomes infected. A toxin has been shown to be responsible for the inhibition of healing. The results suggest that infection occurs after a bit of cankered host tissue containing toxin and mycelium is placed in a wound by an as yet unknown vector. This information will be extremely useful to pathologists investigating this disease. (605,607)

256. Hypovirulent forms of the chestnut blight fungus, which are dominant over the pathogenic wild types, have appeared in Europe. The hypovirulent character can be transmitted to pathogenic strains in such fashion as to suggest that a virus might be associated with this effect. Tests of 11 hypovirulent and 23 virulent isolates indicated that *ds*RNA was present in both. Further tests will be done with other genera of fungi to learn if *ds*RNA may be a more common cellular constituent than had been previously thought. (573)

257. Research on enzymology of forest trees is often hampered because enzymes in extracts from trees lose their activity rapidly after extraction. Tests were made to determine if removal or inactivation of phenolics present in extracts of trees would preserve enzyme (dehydrogenase) activity. Combined phenolic removal and inactivation with sulfhydryl reagents were more effective than inactivation alone. Combined sulfhydryl containing reagents and oxidized nucleotide coenzymes effectively preserved enzyme activity. These results give plant scientists a means of measuring the activities of dehydrogenases present in woody species where previously activity was lost before measurement could be made. (558,559,560)

258. Loss of enzyme activity in crude extracts from trees hinders physiological investigations. To determine if enzyme activity loss is due to proteases in crude extracts, a method was developed to measure proteolysis in crude extracts because existing methods are not sensitive enough. The method developed was based on estimating protease activity with radioactive protein labeled with ^{125} Iodine. This method was found to be an order of magnitude more sensitive than published methods. The method can be used to measure the activity of specific protease enzymes in the presence of other protease enzymes and is not affected by the presence of phenolics found in abundance in extracts from woody plants. (561)

259. *Scleroderris* canker, caused by *Scleroderris lagerbergii*, and shoot blight, caused by *Sirococcus strobilinus*, continue to cause serious losses in pine plantations in the Northern United States. The two diseases have been described and the life cycles of the fungi responsible for the diseases have been presented in a recent publication. Recommended control procedures are discussed for plantation and nursery conditions; these can be used anywhere these diseases are found. (619)

260. Lophodermium needle cast has recently become one of the most damaging diseases of pines in nurseries and Christmas tree plantations in the United States and Canada. The life cycle of the causal fungus has been determined, which has resulted in determining the proper timing of fungicidal and cultural controls. Managers of nurseries and Christmas tree plantations will be particularly interested in this information, since by following the developed control procedures, they can again produce healthy trees. (595,596,597,598,620)

261. A reliable rearing method is needed to provide a continuous supply of pales weevils for conducting research on this serious pest of pine reproduction in the eastern United States. The method that has been developed fulfills the requirement of a continuous supply of insects by producing a ratio of new to parent weevils of over 50:1. The success of this rearing method will

permit continuous research on biological and insecticidal control of this important insect. (451)

262. Procedures are needed to develop white pine blister rust resistance in western white pine. Collections of seed from surviving stands that have sustained high mortality (80–90 percent) due to infection in the Northern Rocky Mountains produce seedlings that are 19.8 percent healthy—an 18 percent increase in resistance over the native population prior to introduction of the disease. Use of this breeding approach will enable forest managers to develop resistance in western white pine by using natural regeneration of surviving trees in areas of high blister rust mortality. (569)

263. An understanding of pales weevil population fluctuations could help avoid losses caused by this major pest of conifer reproduction in the Eastern United States. The effects of temperature, relative humidity, and water submersion on eggs were studied. Temperatures below 24°C. prolonged development; high relative humidities hastened development. Eggs survived submersion in water for 3 days with no adverse effects. Additional studies are needed to properly assess the value of weather patterns for predicting pales weevil populations. (452)

264. Defoliators such as western spruce budworm cause serious damage to our western forests, and silvicultural methods are urgently needed to minimize such damage. Western spruce budworm damage may differ by tree species, which, in turn, could influence management practices. Recent studies showed larval densities were similar on grand fir and Douglas-fir, but grand fir suffered more damage in a given period of time. These findings could influence stand management in the mixed conifer type of eastern Oregon and Washington, since a greater abundance of grand fir would increase susceptibility of the forest to damage by the western spruce budworm. (396)

265. The impact of insect damage on recreational values can be an important factor in an economic analysis of damage, and guidelines are needed to permit such analyses. Tree mortality and top-kill caused by Douglas-fir tussock moth were evaluated on a campground in California in 1970. Cleanup costs of dead and hazardous trees amounted to $23.75 per camp unit; when an esthetic value was assigned to trees, the costs increased to $126.88 per camp unit. Clearly, the esthetic value of campground trees must be considered in determining suppression programs against pests in such areas. (458)

266. Knowledge of the reproductive behavior of the Douglas-fir tussock moth is important for timing egg mass collections and developing a sampling technique using sex attractants or pheromones. Observations were made of adult flight, mating, and oviposition in eastern Oregon. Male flight began at 1000 (PST), increased to a peak at about 1700, and concluded at 1930. This coincided with peak mating activity, and the wingless females oviposited immediately following conclusion of mating. Sticky traps baited with virgin females were very effective in attracting male moths, indicating the feasibility of using the pheromone as a detection and sampling device. (457)

267. Understanding how different hosts influence Douglas-fir tussock moths is necessary to understanding the moths' population fluctuations and epidemics. High density field populations were simulated in the laboratory by forcing larvae to feed on old-growth foliage of Douglas-fir, grand fir, and subalpine fir. This created a stress factor that resulted in increased frass production, development time, and number of instars, in addition to decreasing head capsule size and egg production. Number of eggs produced was greater from foliage obtained from the top of the crown. Understanding these host effects significantly increases our understanding of tussock moth population dynamics and therefore our capability to develop appropriate management strategies to minimize tussock moth damage. (385,386)

268. Christmas tree growers often need to know if the needles damaged by a pest one year would be visible the next year. A life-table for Douglas-fir foliage has been developed showing loss and replacement of needles through time. For example, in a plantation scheduled for cutting in year 10, an insect problem in year 6 on new needles is insignificant since those needles would present only 2 percent of the total by harvest time. With this kind of information, Christmas tree growers are better equipped to make economically sound pest control decisions. (435)

269. Little is known of the adult flight and host selection patterns of the white pine weevil, *Pissodes strobi*, a serious pest of Sitka spruce along the coastlines of Oregon, Washington, and British Columbia. A Forest Service-sponsored study at the University of Washington has shown that most flights occur above 21°C. and the seasonal flight period lasts 7 weeks, peaking during the last 3 weeks of May. The first weevils to fly showed a strong dual preference for leaders on trees not previously infested and for those infested 2 years before. These preferences remained throughout the flight period although at a much diminished level. This basic information significantly increases our understanding of the white pine weevil and increases our capability to minimize its damage. (440)

270. Despite much recent research in insect pathology, no survey of insect and mite virus diseases has been published since 1960. A "Catalog of Virus Diseases" has been prepared that is a condensed summary of a computer-based file of publications on insect and mite viruses. The "Catalog" lists over 600 species of insects and mites, each with one or more of 20 viral diseases or disease groups, for a total of 900 host-virus records. Specific details on virus characteristics can be retrieved from the master file. Use of the "Catalog" will accelerate identification of virus diseases for insect pathologists around the world. (430)

271. Ponderosa pines vary markedly in their resistance to western pine beetles but the factors responsible for this variation are not understood. An inspection of existing data suggests that resistance is strongly affected by resin quantity and quality and by attack density (beetle quantity). Presumably, beetle quality is also important. A formula has been devised describing the role of these factors in establishing resistance of ponderosa pine to the western pine beetle. This formula can assist management in making beetle control decisions and in determining entomological and tree breeding research priorities and programs. (447)

272. Adequate methods have been lacking for predicting white fir mortality caused by the fir engraver and the roundheaded fir borer. Weather and associated tree growth were analyzed for potential use in predicting annual average loss of fir sawtimber. Increases in mortality were preceded by 1 to 2 years of decreased radial growth and one or more years of subnormal precipitation. An equation is provided to help forest managers predict these insect-caused losses. (408)

273. Although shrubs are important vegetation components on big game ranges, watersheds, recreation areas, and homesites, we know very little about their associated insects. A man-

ual, the first of its kind, provides information on hosts, range, damage, and biological information on 43 species or groups of insects and one mite. The manual will help range and wildlife specialists, teachers, students, and others with an interest in native shrubs to better understand both the beneficial and detrimental shrub-associated insects. (409)

274. Understanding the mortality factors influencing survival of mountain pine beetle is essential for understanding the fluctuations of its populations and damage. A mix of mortality factors was analyzed by probabilities of death from specific causes and all causes within single life stages and for the generation as a whole. These analyses provide the basis for discussion of known mortality and hypothetical manipulation of mortality factors. Awareness of how mortality factors operate singly and together will permit additional characterization of the population dynamics of the mountain pine beetle, knowledge that should lead to the development of more effective management strategies. (400)

275. Mathematical models describing mountain pine beetle survival and beetle-caused damage to lodgepole pine could be very important in developing effective beetle management strategies. Current research has shown that the greatest beetle survival and emergence occurred in large diameter trees. After most large trees were killed, gallery starts and egg production continued to increase, but larval survival declined and emergence returned to the endemic level. These observations demonstrate the association of beetle dynamics with diameter structure of lodgepole pine stands, and support the theory that epidemics are strongly dependent upon large trees with thick phloem. Such information will assist foresters in delineating areas susceptible to mountain pine beetle. (401)

276. Management of lodgepole pine can be improved by a better understanding of the variety of insects adversely affecting different stages of stand development. Insects infesting seeds and cones do not appear to cause a major impact, but those infesting terminals cause deformed trees of lower value. Defoliating insects slow growth thus delaying harvest time. Bark beetles are the most serious problem, particularly the mountain pine beetle that typically kills most large diameter trees in a stand. This involved understanding of lodgepole pine-related insects and their damage will benefit our research and protection programs for the lodgepole pine resource. (379)

277. Lodgepole pines attacked by mountain pine beetle sometimes "pitch-out" attacks by resin exudation and the question arises whether this may represent tree resistance. One hundred twenty-nine beetle galleries in 32 recently attacked trees were examined to determine incidence of "pitching-out." With one possible exception, galleries containing no females had been abandoned, although pitching-out had not occurred. Low occurrence of males, which probably resulted in low incidence of female fertilization, is believed to be responsible for most gallery abandonment. Further research is needed to determine the extent of gallery abandonment or "pitching-out" on a population basis before we can accurately assess their roles in limiting the mountain pine beetles' attack success. (380)

278. The Western spruce budworm, one of the most widely distributed and destructive forest insects in North America, has been studied since 1922; yet, much information written on this insect lies in scattered, unpublished reports in R–1 and R–4 offices. This information has now been collected, reviewed, consolidated, and published in one technical report. Summary reports such as this are invaluable for planning future research and pest management projects on this pest problem. (426)

279. Preliminary studies on natural enemies of the southwestern pine tip moth indicated that certain lizards played a role in predation that could be significant in the biological control of this pest. Analyses of 86 lizards stomachs indicated that termites are the major food of the eastern fence lizard in late July and August. Four families of insects and ten families of spiders are reported for the first time as lizard prey. Lizard predation on the southwestern pine tip moth is of little value in the biological control of this insect. (454)

280. Ponderosa and lodgepole pines are native hosts of the mountain pine beetle in the Rocky Mountain area, but this insect also damages Scotch pine that is planted as an ornamental. In urban plantings, the mountain pine beetle attacked and damaged Scotch pine 8.5 inches in diameter (DBH) and larger. The Scotch pines were apparently preferred by the beetle over native hosts, since nearby ponderosa pines were not attacked. This finding indicates that Scotch pine may not be a good choice for ornamental plantings in areas where mountain pine beetles are common. (433)

281. Although bird predation is recognized as a major natural mortality factor of many insects, the individual roles of two closely related flycatcher species were thought to be competitive. The western flycatcher displaced the Hammond's to some degree from aspen-conifer habitat, and was the superior competitor in the study area of southern Colorado. Local coexistence was probably temporary and unstable. Thus, even though the two flycatcher species have slightly different habitat preferences, one or the other will be dominant in a given area, a fact that must be considered when studying the mortality factors of specific insects. (384)

282. Spiders may cause significant mortality of forest insect pests including certain bark beetles. Two female lynx spiders were observed feeding on pine engraver beetles on ponderosa pine in Arizona. Another specimen of engraver beetle was found ensnared in the web of a different spider species. These findings will contribute to a better understanding of *Ips pini* population dynamics and eventual control strategies in the Southwest. (425)

283. The ability to determine the sex of insect pupae is important in many studies where freshly emerged adults are needed. Large aspen tortrix pupae can be sexed by the position and configuration of the genital pore. This finding will greatly facilitate large aspen tortrix research that requires freshly emerged adults. (424)

284. Knowledge of the ponderosa pine tip moth's biology and behavior is necessary to develop management strategies. This insect overwinters in cocoons attached to root collars of ponderosa pine; adults emerge, mate, and eggs are laid in April. Eggs hatch in June and larvae pass through five feeding stages in which needles and then shoots are mined. Eggs are deposited on the inner surfaces of needles in upper crowns of small pines. This information will assist in designing more efficient survey methods and control applications. (422)

285. Abnormally developed insects may sometimes be confusing to identify. A female southwestern pine tip moth pupa with an abnormally segmented abdomen was found in the San Juan National Forest in Colorado. Reports of such abnormal speci-

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mens are very rare. The descriptions of this finding may help avoid future confusion in the event of similar discoveries. (387)

286. The spruce beetle annually kills 300-500 million board feet of spruce in North America; obviously, better management techniques are needed to minimize its damage. Most outbreaks originate in blowdowns, but cull logs may also be a contributing factor. Overmature trees are usually attacked first, but trees in all diameter classes may be killed. Englemann spruce-subalpine fir stands can be rated for potential spruce beetle outbreaks on the basis of physiographic location, tree diameter, basal area, and percentage of spruce in the canopy. Land managers can now determine stand vulnerability to spruce beetle attack and, in some cases, may be able to avoid severe beetle-caused mortality. (443,444)

287. Although phytophagous insects are common elements of most forest ecosystems and occasionally cause widespread defoliation, we understand very little about their long-term effects on the ecosystem. Usually, the number of insects are inversely related to host plant vigor, and normal defoliation, 5 to 30 percent, seldom impairs annual plant production; in fact, it may accelerate growth. Insects can function as regulators of primary production by culling out weakened plants, thereby making the growth-regulating factors—such as moisture and nutrients—more available to remaining vegetation. Understanding long-term defoliator-host interactions and impacts may significantly modify current pest management schemes in many forest ecosystems. (432)

288. Populations of forest tent caterpillar periodically erupt causing severe defoliation of trembling aspen in the Great Lakes Region, and the factors causing these outbreaks are not well understood. Outbreaks in northern Minnesota during 1964–1971 caused 60+percent tree mortality on very wet sites, but only negligible mortality at drier locations. Variations in egg densities were due primarily to survival of early-stage larvae and secondarily to survival of late-stage larvae. Mortality of overwintering eggs depended on severity of winter temperatures. These findings enhance our understanding of the epidemiology of outbreak forest tent caterpillar populations and increase our capability to predict their outbreaks. (460)

289. We know very little about the insects that inhabit the pollen-producing strobili of red pine, even though they could be important factors in limiting seed production. In two seed production areas in northern Minnesota, male strobili clusters had an average of 2-9 insects each, each tree hosted about 4 to 10 thousand insects. Many different species were found including some significant pests such as the jack pine budworm, Zimmerman pine moth, and coneworms. All the strobili-inhabiting insects had a negligible impact on the production of pollen. (431)

290. The sweet-fern underwing is a defoliator and potential biological control agent of sweet-fern, which is the alternate host of an important forest pest, the Saratoga spittlebug. The underwing, a little studied insect, has one generation per year and is attacked by several species of ichneumonid parasitoids. Its potential as a biological control agent of sweet-fern is doubtful due to consistently low population levels and parasitoid attacks. (459)

291. Better communication is needed among the widely scattered membership of biologists, chemists, and other specialists employed by the 267 member organizations of the International Union of Forestry Research Organizations (IUFRO). To help achieve this communication, a world directory of forest pathologists and entomologists has been prepared. Scientists are listed by country with their addresses and research interests. Also included are indices for tree genera, pathogen and insect genera, research interests, and scientists' last names. This bibliography will enhance opportunities for every forest entomologist and pathologist to interact with other forest scientists of the international community. (381)

292. Three thousand acres of sugarberry trees were moderately to completely defoliated in Mississippi by larvae subsequently identified as immature forms of the hackberry butterfly. Toward the end of the outbreak, a virus disease and parasitism were discovered in the population. No noticeable defoliator occurred the following year—an indication of natural controls suppressing the outbreak after only 1 year's defoliation. This infestation should be a useful example in evaluating and understanding infestations of the hackberry butterfly in the South. (450)

293. Sap beetles feed and reproduce in sap spots that heal over and form defects in hardwood lumber; however, the beetles' involvement in the cause of this process has never been clearly established. Recent research has demonstrated that insect borers, not sap beetles, are the primary agents in initiating sap spot in oaks although sap beetle feeding possibly enlarges the sap spot and resulting defect. These results will help to correlate insect-caused degrade and loss with the responsible insect which will be useful in determining research priorities. (448)

294. Basic information has been lacking on the biology of the ash borer, a serious pest of green and white ash in North America. A detailed study in Mississippi revealed this insect has one generation per year; adults emerge March–July, and females deposit 400 eggs during the first 2 days. A description of life stages and larval galleries, distribution, hosts, stand conditions, natural enemies, direct control methods, and status of systematics is presented. We can now effectively recognize the ash borer and its damage as well as prescribe natural, cultural, and direct controls—information of considerable importance—to land managers in the South. (449)

295. Improved procedures are needed for rearing the carpenterworm, a serious pest of oaks and other hardwoods in the Eastern United States. An artificial diet was formulated into partially dried cakes and presented to larvae in disposable plastic rearing containers. Almost 60 percent of established carpenterworm larvae survived on this substrate. This diet reduces microbial contamination and frequent handling and provides an acceptable procedure for rearing and maintaining a supply of carpenterworms for research purposes. (429)

296. Mites are known predators of the southern pine beetle and other bark beetles, but identification methods to differentiate mite species has been lacking and this hampers biological control evaluations. Current research has provided a key and other descriptive information to identify the mites preying on the southern pine beetle. Several new species have been described and a number of species have been identified as particularly promising biological control agents. A firm basis has now been established to evaluate the potential of both native and exotic mites as biological control agents of the southern pine beetle. (402,436,437,438,439,445)

297. Before predatory mites can be evaluated as control agents of bark beetles, reliable procedures to identify them by species are needed. The five species of *Histiostoma* associated with the southern pine beetle have been one of the more difficult groups to separate by species. In part, this difficulty reflects the fact that *H. conjuncta* was known only from the phoretic (nonfeeding) stage. The recent discovery of the female, male, and immature stages of this species now makes the group easier to identify, allowing biological control workers to test the species for predation on the southern pine beetle. (461)

298. Researchers and land managers have speculated that host tree resistance to southern pine beetles may be lessened by moisture stress which, in turn, may affect the composition of xylem oleoresin. Recent research has indicated that moisture stress decreased the proportion of resin acids relative to monoterpene hydrocarbons in the oleoresin. Changes were more pronounced on poorly drained sites and in trees with deficient root systems. Research must now be continued to relate these changes in oleoresin composition to southern pine beetle susceptibility. (415)

299. Although mycorrhizal fungi form a necessary part of the larval southern pine beetles' diet, we have not previously known their release site in the mycangium. The primary method of inoculation of spores into the gallery is by release along the edge of the presternum with the spores coming from openings in the sternum and/or the anterior thoracic fold. This information is important for other researchers using the scanning electron microscope to demonstrate release of mycangial fungi and to elucidate the biology of these fungi. (382)

300. Mycangial fungi are important associates of the southern pine beetle, and an understanding of their biology and identity are essential to pest management research. The yeast stage of *Sporothrix* sp. (SJB 133) is similar to that of *Sporotrichum schenckii*. The SJB 133 *Sporothrix* differs in several respects, including (1) the cell wall of the yeast-stage had low affinity for electron stains; (2) cells tended to be pyriform; and (3) distinct paramural pockets were observed in SJB 133. SJB 133 produces a phase in the mycangium that provides "Propagules" to be released into the beetle gallery. These results explain how mycangial fungi are related to filamentous forms and how they reproduce before release into the beetle gallery. (412)

301. Information on bark and timber beetles, related microorganisms, and host trees is scattered widely throughout the literature of several disciplines. A recently published bibliography lists 244 abstracted articles published between 1965 and 1974 arranged alphabetically by senior author. This bibliography is a valuable research tool for all scientists interested in scolytid development, symbiotic relationships, and woody host tissue interactions. (383)

302. Insect response to pheromones is highly specific and slight changes in structural chemistry can greatly influence the biological activity upon which control or survey applications may depend. Initial reports of the aggregation pheromone produced by the European elm bark beetle, the principal vector of Dutch elm disease, described nonstereospecific synthesis of the pheromone that yields four isomers. Stereospecific synthesis procedures are needed that will permit particular structural assignkents of these isomers. Recent research has discovered the stereochemical assignment for the C-2 and C-4 methyl groups in the four isomers, as determined by chemical and spectrometric data. This information is important for determining the relationship between molecular structure and biological activity and, ultimately, for success of survey or control applications. (411)

303. A means to chemically disrupt spermatogenesis of the smaller European elm bark beetle, principal vector of Dutch elm disease, could limit the insect's reproduction and damage capability. Thus, an understanding of reproductive biology is necessary before effective tests can be undertaken. Testicular volume increased rapidly during larval and early pupal stages, reaching a maximum in the pupal stage and declining in the adult. Spermatocytes, spermatids, and spermatozoa were all found in the adult, indicating that spermatogenesis continues into this stage and that adults are susceptible to treatment. This information is of fundamental importance should the control approach of limiting reproduction by disrupting spermatogenesis ever be implemented. (428)

304. Laboratory rearing of forest insects is often essential to insure a continuous supply of uniform research specimens; yet, recent research has demonstrated that rearing red oak borers in continuous light caused them to be sterile. The sterility is thought to have been caused by the destruction of specific vitamins. Successful laboratory culture of the red oak borer requires further study to determine the explanation of this problem and to ascertain other potential problems. (410)

305. The redhumped oakworm is an important pest of oaks in the north central region of the United States, and land managers need easily understood, accurate information about this pest to assist them in making control decisions. A popularized report is now available that describes the oakworm's biology, natural enemies, cyclic habits, and impact of defoliation. This information will assist land managers and other persons in dealing with outbreaks and will inform the public of the pest and its characteristics. (434)

306. Predatory mites can be important agents for biological control of insects, but we need more basic biological information about them before we can assess their value in biological control programs. Recent studies contribute to the knowledge of how photoperiod and temperature can influence induction and duration of diapause (resting stage) of a predatory mite. The importance of alternate prey species during a particular time of year is also emphasized. We now have a better understanding how two very different factors may limit the activity or distribution of a potential natural control agent. (416,417,421)

307. Although biological control is already a significant factor in the natural control of some forest insects, it may be possible to genetically improve the effectiveness of some biological agents. Essential to such programs are clearly-defined attributes of the parasitoid, adequate genetic variability, proper selection procedures, and maintenance of the desired characteristics. Hybridization of geographic strains of parasite species is one approach to accomplish the desired quality improvement. Some promising results in this direction have been obtained with *Apanteles melanoscelus*, a gypsy moth parasite. More work is needed to elaborate this approach, but breeding of parasitoids could significantly improve the effectiveness of biological control of gypsy moth and other pests. (418,419,420)

308. Biological agents are important factors in controlling some forest insects, but improved methods are needed for evaluating the effectiveness of individual parasites. Because parasit-

ism of the variable oak leaf caterpillar by *Diradops bethunei*, a parasitic wasp, causes reduction in head capsule size of the caterpillar hosts, the rate of parasitism can be determined from host head capsule measurements. This technique provides a quick, accurate assessment of the rate of parasitism by this parasite without time-consuming dissections of the caterpillar larvae. (453)

309. The gypsy moth is the most important defoliator of hardwood forests in the Northeastern United States, and better information is needed on its egg mass distribution and population dynamics to facilitate pest management decisions. Recent research has provided information on how to find egg masses and pupae and assess their value in predicting population trends. An interactive model is also provided that relates tree vigor, defoliation, and mortality to egg mass density. Land managers are now better equipped to detect gypsy moth populations, predict damage, and make control decisions. (389,390,392,394,455,456)

310. The gypsy moth is the most important hardwood defoliator in the northeastern United States, and managers, homeowners, and other interested individuals should be able to distinguish the different life stages of this moth and recognize some of its natural enemies. Two publications discuss all aspects of gypsy moth biology, habits, and natural control. The photographs and color drawings are invaluable for essay identifications. The public now has the information to understand some of the complexities of gypsy moth biology and to readily identify this insect and its natural enemies. (391,462)

311. Contrary to the regular oscillations characteristic of gypsy moth populations across much of Europe, populations in North America are characterized by two numerical phases of greatly varying duration. A recent study of populations in an outbreak area and in an innocuous area reached several conclusions relating to egg production, instar survival, and sex ratios. Further studies along similar lines should greatly increase our understanding of gypsy moth population phases which, in turn, should enhance our capability to develop effective pest management systems to minimize gypsy moth damage. (393)

312. Although the pales weevil is the most serious insect pest of pine reproduction in the eastern United States, we lack considerable information about its biology and habits. Recent research has shown that adult weevils do not reproduce in the winter months and that dietary sterols are essential for larval survival and growth. These results indicate that foresters (1) can plant in winter without concern for weevil buildup and (2) that researchers should consider sterol fluctuation in host trees as a possible factor influencing weevil populations. (398,441)

313. We cannot accurately predict population trends of the elm spanworm, an important defoliator of hardwoods in the southeastern United States. A study of leaf quality indicated that adult longevity increased when larvae were fed on hickory instead of oak foliage. Juvenile leaves favored spanworm development more than mature leaves, a fact probably related to a decreasing concentration of major fatty acids with leaf maturation. Leaf sterols varied little throughout the growing season. A more complete understanding of spanworm nutrition could assist in predicting the occurrence and duration of spanworm outbreaks. (399,403)

314. The need for effective insect control agents coupled with environmental safety concerns has encouraged a search for more selective insecticides. These materials can perhaps be synthesized if the chemical requirements of the active surface of the target enzyme can be established. A number of acetylcholinesterase inhibitors were synthesized and tested on insects and other animals. Differences with respect to enzymatic binding, reactivity, and penetration to the site of action were observed. These findings contribute to a better understanding of the toxicological differences between species that may be exploitable for development of selective insecticides. (413)

315. Because of the growing concern to develop environmentally safe pesticides, more specific information on pesticide degradation is needed. Five forest fungi were evaluated for their effectiveness in degrading Aldicarb, an insecticide commonly applied to soil. In decreasing order of effectiveness, the fungi were: *Gliocladium catenulatum*, *Penicillium multicolor*, *Cunninghamella elegans*, *Rhizoctonia* sp., and *Trichoderma harzianum*. Apparently, Aldicarb would not be persistent enough in forest or nursery soils to cause environmental problems through residue buildups. (427)

316. Because methylmercury hydroxide increases the toxicity of the insecticide carbaryl in rates, there is concern that mercury in combination with carbaryl could prove detrimental to man. Since carbaryl is considered to inhibit acetylcholinesterase, an enzyme involved in nerve mediation, the effect of methylmercury on this enzyme and a blood plasma enzyme, butyrylcholinesterase, was assessed. Methylmercury was not a direct inhibitor of these enzymes but it did seem to decrease enzyme synthesis. These findings contribute to the understanding of methylmercury influences on insecticide toxicity, an important consideration directly related to environmental safety and EPA registration of insecticides. (414)

317. Parasites are important biological control agents of forest insects; consequently, careful biological evaluations are needed for foreign parasites being considered for introduction into the United States. A European parasite, *Olesicampe benefactor*, is highly effective against larch sawfly in central Canada, and is now recommended for introduction into New York and Pennsylvania. Another parasite of several European sawfly species, *Monodontomerus dentipes*, is already established in the country and a detailed study of its life history was made to facilitate its effectiveness in controlling several species of nature sawflies. These studies provide guidelines for determining the suitability and improving the effectiveness of two European parasites for control of nature sawflies. (404,407)

318. A vast array of insects damages Southern forest trees, and identification of damage and causal agents can be very difficult. This report illustrates major insects and their damage. The illustrations are supplemented by a popularized text and keys readily understood by the layman or professional. Land managers now have a useful guide to identify Southern forest insects and the damage attributable to them. (406)

319. Illustrated, accurate, and easily understood information on insect problems in Southern pine seed orchards has long been needed by orchard managers, foresters, and entomologists. A recently prepared guide provides color illustrations and written information on 22 insect species and their related damage. Identification keys are designed for both laymen and professionals. Distribution maps, host tables, and graphs depicting principal periods of damage are further aids to species identification. Orchard managers now have the basic information to determine

damage assessments and control strategies for seed- and cone-damaging insects. (405)

320. Blister rust disease is a major limiting factor in growing western white pine in the Rocky Mountain region. A new mechanism of resistance has recently been observed. The mechanism is a hypersensitive reaction that developed in needles of *Pinus armandii* in response to infection by *Cronartium ribicola*. Knowing how to recognize this reaction will probably lead toward its discovery in *Pinus monticola*, and, subsequently, make it possible to increase its frequency and importance in this species. (568)

321. Although the spruce beetle annually kills 330-550 million board feet of spruce sawtimber, we lack sufficient understanding to effectively reduce these losses. A popularized account of the beetles' biology, life history, and natural control factors has been published. Clearcutting in irregular patches with disposal of cull logs is suggested as the most promising method of reducing spruce beetle losses. Thus, the suggested silvicultural and sanitation practices need to be tested on a large enough scale to determine their efficiency and practicability. (442)

Pest control techniques

322. Bordeaux mixture effectively controls brown spot needle blight of longleaf pine seedlings; however, this fungicide is difficult to prepare and is corrosive to spray equipment. To find a satisfactory substitute several fungicides were evaluated. Chlorothalonil was effective and could be used in place of Bordeaux mixture in the South. (645,652)

323. Methods for successfully introducing specific ectomycorrhizal fungi into nursery soils, so that "tailor-made" tree seedlings with ecologically adapted ectomycorrhizal fungi can be produced, have been lacking. Successful methods have now been developed by which *Pisolithus tinctorius*, artificially introduced into nursery soils, infect and stimulate growth of loblolly pine seedlings. Foresters and nurserymen by use of the methods can now be assured that beneficial ectomycorrhizal formation will occur on roots of loblolly pine seedlings growing in fumigated nursery beds. (637,647,648,650,651,649)

324. Dwarf mistletoe infections can increase on young ponderosa pines selected for crop trees, thus diminishing production in managed stands. Infection can be reduced by pruning from the top, leaving a basal skirt of lower branches for photosynthesis until new, infection-free branches develop at the top of the tree. In a test of this method, pruned trees grew in height as well as unpruned trees but suffered a loss in diameter growth. Top-pruning appears to be a sound silvicultural method in mistletoe-infected, second-growth ponderosa pine stands in the Pacific Northwest. (646)

325. Fungi which cause root diseases are often difficult to control because of their tendency to spread naturally from infected to adjacent healthy root systems below the soil surface. Field trials were run to test the hypothesis that a band of roots killed by soil fumigation with methyl bromide would be unsuitable for invasion by *Fomes annosus* and would block the underground spread of this fungus from diseased to healthy trees. *Fomes annosus* was contained by fumigation in 11 of 13 infection centers located in red pine plantations in the Northeast. This information will help researchers and forest managers alike in developing methodology for controlling root rots. (644)

326. Better methods are needed for treatment of tree wounds to minimize decay development. The development of decay was inhibited for a year in wounds on red maple which had been inoculated with *Trichoderma viride*. The use of such a biological control method could be of great benefit in reducing the impact of decay in trees, especially in light of other research which points out that the commonly used wound dressings do little to stop decay. (653,654)

327. *Rhizosphaera* needle cast disease is currently causing serious damage in blue spruce Christmas tree plantations in Wisconsin, Michigan, Minnesota, and Indiana. Field tests have shown that Bordeaux mixture, benomyl, chlorothalonil, and a mixture of chlorothalonil and cycloheximide effectively control this disease. Two fungicide sprays applied in June and July provided the most economical control. This information can be used anywhere in the north central and northeastern areas where *Rhizosphaera* is damaging blue spruce. (656,657)

328. Before preparations of nucleopolyhedrosis viruses can be registered for use, methods must be found to clear the virus suspensions of certain bacterial contaminants introduced during mass production of the suspension. Sodium Omadine treatment is a rapid, inexpensive method for eliminating virus suspension contamination and should accelerate operational development of virus-based insecticides. Sodium Omadine was used to eliminate the bacterial contaminant from the European pine sawfly virus suspension. Neither the treatment nor the elimination reduced the effectiveness of the latter. (470)

329. The larch casebearer, a serious defoliator of larch in the United States was introduced into the West without any of its natural enemies. Because biological control of the casebearer by parasites is considered promising, a continuing program is underway to propagate, introduce, and evaluate parasite species. Methods have been developed for continuous laboratory rearing of the casebearer along with several parasite species and geographic strains of some parasite species are being evaluated for clarification of their taxonomic designations. A continuing program of parasite release and follow-up sampling to evaluate effectiveness is underway. In a few years, this research should demonstrate the effectiveness and feasibility of controlling larch casebearer by parasite introduction. (493,494,495)

330. Can the Douglas-fir tussock moth's sex pheromone be used to develop a more sensitive detection system for potentially destructive populations of this very explosive pest? To answer this question, chemical identification of the pheromone was necessary. The attractive compound has been identified as (Z)-6-heneicosen-11-one, and this material, now synthesized, has proved an extremely potent attractant in both laboratory and field. Traps baited with this compound are being developed to detect increasing moth populations, a prerequisite to defining areas requiring intensified surveillance and possible control measures. (500,501)

331. The European pine shoot moth is a pest of pine regeneration in various parts of the world, and new, environmentally-acceptable control strategies are needed to minimize its damage. The shoot moth's pheromone, (E-9-dodecenyl acetate) and a pheromone inhibitor, (Z)-dodecenyl acetate, were compared for their effectiveness in disrupting sex pheromone communication. Area-wide dispersion of the pheromone caused 97 percent and 100 percent reductions in male attraction to synthetic and live-female baits whereas the pheromone inhibitor produced 0 per-

cent to 63 percent reduction, respectively. Thus, the pheromone is the better compound to develop as a behavioral control agent of this insect. (467)

332. Considerable information is available on aerial spraying for control of forest insects, but it is widely scattered among many reference materials. A tabular history of aerial spraying of American forests to control insect damage has been prepared. Acreage sprayed in a given year is listed by insect and insecticide. Nearly 31 million acres have been sprayed since 1945; four insects (western spruce budworm, gypsy moth, spruce budworm, and Douglas-fir tussock moth) have been the target for 96 percent of the operations, and three insectides (DDT, Sevin, and Zectran) have been used on 97 percent of the acreage. This record is a valuable reference for anyone involved with forest pest control. (496)

333. Mountain pine beetle is a major pest of ponderosa pine over much of the West, and methods are needed to decrease its damage. Greatest damage occurs where stand density is so high that competition has slowed growth of even the dominant trees. Field experiments and computer simulation studies indicate that thinning deserves major emphasis in programs to combat this pest. An eastern Oregon test monitored for 5 years showed that thinning reduced mortality by 90 percent and increased stand growth. The value of thinning to reduce mountain pine beetle damage has been demonstrated on a near operational scale; further work should demonstrate for how many years the treatment will remain effective and whether it is appropriate under different conditions. (497,498)

334. Outbreaks of Douglas-fir tussock moth have periodically devastated Douglas-fir and true firs in western North America, and environmentally acceptable control strategies are urgently needed to alleviate this problem. Experimental aerial applications of nucleopolyhedrosis virus and a bacterium, *Bacillus thuringiensis*, provided satisfactory foliage protection and essentially eliminated the insect from the treated plots. The success of these tests moved the two tested materials one step closer to EPA registration as operational control agents for the tussock moth. (502)

335. Microbial control agents are among the most promising of the new environmentally acceptable approaches to pest control; however, numerous safety and application problems must be solved before the effectiveness of these materials can be optimized. Considerable information is now available from many studies on spray systems, marking methods to guide aerial applications, physical properties of spray formulations, use patterns, and distribution on foliage with related effectiveness on target pests. Collectively, this information will assist those planning future applications of microbial materials. (476,477,478,479,480,486)

336. Aerial spraying to control specific insect pests must be accomplished with the minimum possible damage to nontarget organisms, and monitoring residue levels is an important method of determining possible harmful effects to wildlife. Trichlorfon and lauroyl trichlorfon, two insecticides potentially useful for controlling the western spruce budworm, were sprayed over a variety of foliage and water. Residues of both materials disappeared from the foliage in 2 weeks and from the water in about 2 days. These materials appear to present no unknown environmental hazards; thus, their continued use as experimental materials for possible control of western spruce budworm is justified. (489)

337. There is a continuing need to identify promising insecticides for control of the western spruce budworm, one of the most destructive forest defoliators in North America. Only malathion and mexacarbate are currently registered for aerial suppression, and mexacarbate is no longer commercially available. Of over 100 candidate insecticides screened over a 10-year period, pyrethroids were generally the most toxic. Several of these highly promising insectides warrant further development as potential control agents of western spruce budworm. (491)

338. Better control agents are needed for the cottonwood leaf beetle which is a serious defoliator of young cottonwoods throughout North America. Spray chamber tests of 21 insecticides on adult beetles and seven insecticides on larvae were conducted to find candidate materials for use in nurseries and plantations. All candidates were more toxic than DDT to both larvae and adults. Some of these materials were selected for field testing in Mississippi, and carbofuran is now registered for control of this insect in cottonwood plantations. (487)

339. Better controls are needed for hemlock sawfly and the western hemlock looper, serious pests of western hemlock, spruce, and true firs in western North America. No chemicals are registered for use against hemlock sawfly and only malathion is registered for use against western hemlock looper. Of the test chemicals, tetrachlorvinphos and resmethrin were most effective against the sawfly, and pyrethrins were most toxic to the western hemlock looper. These data strongly support further studies, including field evaluations, of candidate control agents against hemlock sawfly and western hemlock looper. (492)

340. Insufficient supplies of endo-brevicomin have hampered recent field testing of pheromones to control destructive bark beetles. An efficient method of large-scale synthesis was developed that yielded no contaminating exo-isomer, a recurring problem in previous syntheses. With an assured supply of endo-brevicomin, adequate field-testing of pheromone response can be conducted for both the southern pine beetle and the western pine beetle. (475)

341. Silvicultural treatments are effective means of managing beetle populations and damage; however, in areas where cutting is not possible, other methods—such as pheromone treatment—are needed. Eight hundred trees adjacent to logging roads were baited with "Douglure" which contains frontalin, a principal component of the Douglas-fir beetle aggregative pheromone. Beetles were strongly attracted and spilled over into the surrounding stand at the rate of nine additional trees for each treated tree. In 56 percent of the attacked trees, the beetles failed to become established. These results will facilitate testing and development of frontalin for suppressing Douglas-fir beetle populations. (490)

342. Mountain pine beetle-infested material is often cut for firewood in Colorado, and the beetles can mature and become a source of infestation when the wood is moved to new locations. The beetles can be killed in ponderosa pine firewood by spraying each cord with 2 gallons of ethylene dibromide emulsion and then covering and sealing the wood piles with plastic. This is a simple and inexpensive means of preventing the spread of beetles from infested wood. (482)

343. Pinyon needle scale is a serious pest of pinyon pine in the Southwest. A cartoon-format leaflet has been developed to pro-

vide how-to-do-it information on controlling scales by working their egg masses off trees with a water spray and then destroying them. This is a simple, inexpensive control method not involving the use of pesticides that is available to any homeowner. (471)

344. Trap design is an important factor in the efficient use of insect attractants. An inexpensive trap for the southwestern pine tip moth was constructed from an ice cream carton and a board. Caged virgin females were used as baits. The use of this trap will facilitate studies to evaluate sex attractants of tip moths and possibly other species. (473)

345. The Malaise trap is widely used to collect flying insects; however, it is subject to wind damage when used as originally designed. The standard trap has been strengthened by using a bronze screen funnel and a framework of angle iron and aluminum tubing. The modified trap is only slightly more expensive than the standard and it is much better suited for use on the windswept sagebrush rangelands of south-central Wyoming. (499)

346. Scotch pine varieties vary in their resistance to Zimmerman pine moth and this resistance may be useful in controlling damage by this pest. Varieties suffering heaviest damage were from England and central Europe seed sources. Northern and Southern European varieties were similar in susceptibility, but generally less susceptible than those from central Europe. Varieties with lowest mortality by the moth also contained the lowest concentrations of the monoterprene, 3-carene that appears to be an attractant. Christmas tree growers may now be able to develop and plant Scotch pine varieties with more resistance to Zimmerman pine moth. (506)

347. Better control agents are needed for the forest tent caterpillar, a hardwood defoliator whose feeding has reduced host diameter growth 50 percent or more and prevented seed production in one-half million acres of water tupelo forests in southern Louisiana. Trichlorphon (Dylox®) applied at three-quarters of a pound per acre provided nearly 100 percent control of this insect with minimal effect on associated nontarget organisms. It is now registered by EPA. Forest managers now have an effective, environmentally acceptable insecticide to protect water tupelo from forest tent caterpillar. (484)

348. Insect pheromones offer much promise for insect survey and control applications; however, improved techniques are needed for collecting sufficient quantities of these volatile compounds to permit their identification. Several organic compounds similar to insect pheromones were removed from an airstream by absorption on Poropak Q. Application of this method to the aeration of live insects yielded a Porapak extract that concentrated the pheromone given off by the insects. This technique offers a new practical means of collecting pheromones and other volatiles that will be useful in their structural identification and evaluation as survey or control tools. (388)

349. An improved apparatus was needed for pressure-injecting fluids such as systemic pesticides into trees. Weight reduction of an existing system was achieved by use of a plastic fluid reservoir. The valving system was modified as were the injector heads to permit quick and secure attachment to the tree with duplex nails. Fungicides, insecticides, herbicides, and any other liquids can now be rapidly injected into the vascular system of trees with minimal impact on the environment. (472)

350. A practical technique is required to detect smaller European elm bark beetles in areas where their presence is unknown. To develop pheromone trapping methods, recent studies evaluated trap height and explored the relationship of captured beetles to beetle distribution and abundance. The pheromone-trapping survey technique will find widespread use in the United States and abroad for mapping beetle distribution, determining beetle abundance, and timing a variety of control programs. (488)

351. The value of *Bacillus thuringiensis* (*B.t.*) as an insect control agent has been known for some time, but improvements in formulation and application methods are needed to optimize effectiveness of treatments. Using molasses in formulating *B.t.* helps to overcome adverse gypsy moth feeding response to certain concentrations and preparations. The crystals did not elicit a discriminate type of feeding. These findings expand the potential and opportunities for successful operational use of *B.t.* against the gypsy moth and other forest insects. (507)

352. The use of baculoviruses for insect control can have short- or long-term effects depending on dosage effects and methods of application. This report contrasts short-term effects on gypsy moth (no carryover to the next generation) with long-term effects on the European pine sawfly (significant carryover). Land managers and users of baculoviruses must know what to expect of these agents and how to use them to achieve the maximum beneficial effect. (474)

353. Microbial insecticides are among the most promising approaches for environmentally safe control of forest insects, and definitive serological identification techniques are necessary for some of these materials, particularly the viruses. These reports describe the technique for obtaining antisera, and the use of the antisera to show serological similarities and differences between viruses of gypsy moth and a sawfly. The present state of knowledge concerning baculoviruses is analyzed, and solutions are offered to resolve the present confusion on methods. Standardized serological procedures are necessary for the comparison and testing of different nurseries and to obtain EPA registration for their use in control programs. (481,485)

354. Effective and environmentally safe insecticides are needed to minimize damage by the gypsy moth which continues to spread and defy a wide range of control actions. Gardona was recommended for field testing based on laboratory screening and backpack mistblower field tests. Two concentrations were applied by helicopter; both gave similar results and neither showed any significant differences with the check. Gardona failed to reduce gypsy moth populations because the study area had above-average precipitation, the spray coverage was light, and the residues dissipated rapidly from the leaves. (463)

355. Increasing registration restrictions and environmental concerns necessitate new ways to improve the infectivity and selectivity of microbial and chemical insecticides. A number of soil microorganisms were found with marked ability to dissolve the Chitin-containing mycelium of a test fungus. If topical applicants could be developed that specifically dissolve Chitin, such a material, if added to an insecticide, might significantly increase its effectiveness. (483)

356. Pheromones (attractant chemicals) are among the more promising new agents for insect control, but improved methods are needed for dispensing these materials in the forest. For the first time, an aerosol formulation of an insect pheromone was

developed and field tested. Initial results with the southern pine beetle were promising although improved quality of the aerosol and modifications of the disperser are needed. With specific improvements, a pressurized aerosol formulation of pheromone could become a valuable tool for research and for insect survey and control. (504)

357. Egg parasites are valuable biological control agents of forest insects such as fall cankerworm, but considerable biological information is needed for each parasite species before any can be recommended for introduction. A new species of *Telenomus* controlled a recent outbreak of elm spanworm in the southern Appalachians, and this parasite also attacked a related hardwood defoliator in Colombia, South America. *Telenomus* would appear to be an important parasite for elm spanworm, fall cankerworm, and possibly other species. (469)

358. Better insecticides are needed to control southern pine insects. Two systemics, Orthene and Monitor, were evaluated for insecticidal activity and persistence in loblolly pine. Root dips of Orthene protected seedlings for 60–90 days; translocation and persistence in the seedling were greater in root-dipped seedlings than in seedlings treated by soil drenching. Monitor had high insecticidal activity but was 90–95 percent metabolized within 5 days. Orthene would seem to be a useful insecticide for Southern nurserymen pending its suitable registration with EPA. (505)

359. Low seed yields in seed orchards and in controlled pollinations have hampered breeding progress in southern pines. Insect damage and lack of proper pollination techniques have been shown to contribute to the high seed losses. Lack of viable pollen and seedbugs frequently cause first year ovule abortion. Spraying Guthion in a slash pine orchard in Georgia shows promise of high seed efficiency. Improved controlled pollination techniques and insect management can lead to greater genetic improvement in southern pines. (360,468)

360. Walnut anthracnose is a disease which causes black walnut trees to lose their leaves early and incomplete maturing of nuts, a symptom known as "ambers." Anthracnose has been controlled using benomyl, either as a soil injection or a foliar spray. Better growth from anthracnose controlled trees is expected in plantations in southern Illinois. (636)

361. Coating seed with endrin is the operational method currently employed with direct seeding, but impregnating seed with such a chemical has been a long-sought goal. Research has shown that field-sown Douglas-fir seeds coated and impregnated with endrin produced much greater stocking and many times more seedlings than untreated seed, although there were no significant differences among the coating and impregnating treatments. Results reaffirmed the need for protection and clearly demonstrated that sites to be seeded must be carefully selected and sown when climatic conditions are favorable. (465)

Pest management strategies

362. Forest pest management is an integral but poorly understood aspect of forest resource management. A realization that forests are dynamic ecosystems providing renewable resources for many human needs accentuates the necessity to consider a great diversity of factors in developing pest management programs. The basic components of forest pest management systems and essential steps in their development are outlined. In addition, current practices and future needs for pest management in various forest types are discussed. This information provides conceptual guidelines and specific recommendations for the development of forest pest management systems—a critical need for the maximum use of forest resources. (521)

363. Operational use of attractant-based (pheromone) suppression and survey techniques for bark beetles depends on large-scale demonstrations of their efficacy. A recent large-scale trap-out test in California against the western pine beetle appeared to (1) substantially reduce beetle populations and (2) contribute to a reduced beetle-caused tree mortality in the test area. Pending final data analysis, this test may be the first successful operational-scale use of attractants to suppress a forest insect pest. Further field or pilot testing should confirm whether this technique is an effective and economical strategy to reduce western pine beetle damage. (508)

364. Male *Ips* bark beetles produce aggregating pheromones that may be useful in survey or control operations if response specificity can be adequately determined. Seventeen species of *Ips* were tested for their specificity to the male produced attractant. Closely related species were cross-attracted, but distantly related species were not. This knowledge should facilitate development of pheromone-based, operational suppression and survey methods for *Ips* bark beetles. (514)

365. Available information on research and management of mountain pine beetles has not previously been condensed and published in a nontechnical form for foresters and other land managers. Such a guide has now been provided. This information will be useful to practicing foresters seeking ways to minimize mountain pine beetle losses in lodgepole pine stands. (510)

366. A periodic review and updating of elm bark beetle research information is necessary to adequately plan and coordinate Dutch elm disease research programs. This report summarizes past research, elaborates information on significant recent findings, and discusses future programs. This information will be useful to all researchers planning programs directed toward integrated elm bark beetle management. (517)

367. Dutch elm disease threatens to eliminate elms as a shade tree species in urban areas, but this damage can be minimized by conscientious applications of various control measures. A study of the importance of root grafts and bark beetles in the spread of the disease indicated more emphasis should be given to reducing root grafts. Control strategies primarily involve reducing bark beetle habitat and prevention of transmission through root grafts. Communities that have experienced the fewest elm losses have a sound program of several control strategies applied conscientiously over a period of years. This information can be used to good advantage by any community willing to mount a conscientious effort to save its elm trees. (509,513)

368. The integrated use of insect-suppression agents has been frequently discussed but little practiced. Both commercial preparations of *Bacillus thuringiensis* (*B.t.*) and the introduced parasitoid *Apanteles melanoscelus* have, under certain conditions, provided significant reductions in gypsy moth populations and provided some measure of foliage protection. Recent research has shown that treating a gypsy moth-infested area with *B.t.* followed by release of the parasitoid, A. melanoscelus, provided a greater reduction in pest populations and an increased level of foliage protection than either agent used singly. Additional research to refine application strategies and test other possible control agents may well provide land managers with a feasible integrated approach to gypsy moth control. (522)

369. Shade trees, while of concern to millions of American families, have a multitude of insect problems, the sum total of which are being studied by fewer than two dozen researchers. This report discusses a variety of pest control approaches and emphasizes utilization of parasites, predators, resistant tree varieties, and selected biological pesticides. Specific recommendations are also given in an attempt to resolve specialty-use pesticide registration problems. The International Shade Tree Conference now has the information and guidelines necessary to significantly influence future developments in shade tree entomology. (519)

370. Information on protecting seed orchards from a variety of destructive agents is widely scattered in the world literature. Now, worldwide operational procedures for protecting seed orchards from insects, diseases, mammals, birds, fire, and weather conditions such as frost, ice, and snow are discussed in one paper. This review provides a reference to the world literature on seed orchard protection that will be invaluable to all seed orchard operators and managers. (518)

371. Pales weevil is the chief insect threat to pine reproduction in the Eastern United States, and effective, environmentally safe control agents are needed to minimize its damage. Various formulations and treatments of Dursban (chlorpyrifos) and Furadan (carbofuran) were tested. This research led to the EPA registration of three formulations of these chemicals for pales weevil control. Additional information is provided on treatment strategies based on a hazard classification of the lands to be planted. Pine planation managers now have several strategies to prevent pine reproduction losses caused by pales weevil. (516,520)

IMPROVING THE WATER RESOURCE

Water quality

372. Knowledge of the impact of timber harvesting on stream water quality is needed for different ecosystems. In the cedar-hemlock-grand fir ecosystem of the northern Rocky Mountains, changes in water quality caused by clearcutting and subsequent slash burning were evaluated. Significant nutrient increases occurred in stream flow through treated sites. Increases were small at downstream locations, except for one stream where downstream nutrient uptake increased as water moved laterally through nutrient enriched surface layers. Buffer strips are effective as physical barriers to direct contact with the nutrient source. (153)

373. The interruption of plant nutrient cycling by clearcut harvesting may release chemicals into soil and water systems. Old growth lodgepole pine in northwestern Wyoming was clearcut and four different methods of debris disposal were applied. Clearcutting caused insignificant nutrient increases. Burning of debris only slightly increased the release of some elements, but mulching with finely-divided logging debris caused considerable organic pollution of the soil solution in the first post-treatment year. (151)

374. Little has been reported on streamflow water quality from upland peatland watersheds. A study in north-central Minnesota shows concentrations of organically derived nutrients to be highest in the streamflow from watersheds containing oligotrophic peatlands. Concentrations of nutrients derived from solution of aquifer minerals are higher in streamflow from a watershed containing a minerotrophic peatland. Annual nutrient yields from upland-oligotrophic peatland watersheds are generally low and quite similar to values for other forested areas without peatlands. These data provide input to lake classification models and nutrient budgets for evaluating forest site productivity. (156)

375. Stream chemistry changes are presented for 24 streams draining both disturbed and manipulated forests. When compared with undisturbed watersheds, a grass-to-forest succession watershed that had been fertilized, limed, and herbicided showed larger losses of ions except for PO_4-P. Where the forests were cut and in various stages of natural revegetation, elevated NO_3-N discharge was evident at least 10 years after cutting, but appeared to return to baseline levels 20 years after treatment. Even mature deciduous forests that were partly defoliated by insects showed an increased discharge of NO_3-N. Conversion of deciduous forests to white pine reduced the loss of most nutrients, and young coppice forests exhibited nutrient cycles that lose no nutrients than mature hardwood forests. The results are useful in evaluating the long-term impacts of alternative forest management practices on nutrient losses in the southern Appalachians. (154)

376. The change in water quality resulting from current mining and reclamation methods is important to the maintenance of aquatic life and to downstream water users. Basic to determining change in water quality is good information on pre-mining levels of potential pollutants. Investigations in West Virginia comparing water quality characteristics from watersheds before mining with the same characteristics after mining showed significant pre-mining variation, depending on annual climatic variations and season of the year. The study indicates that correct mining methods can be employed to reduce adverse effects on stream quality. (152)

Water yield and timing

377. When a small watershed is clearcut, it temporarily yields more water, but what happens when the trees are killed by insects, disease, or fire on an area covering several hundred square miles? Data from two large watersheds in Colorado showed that substantially greater yields are evident 25 years after a bark beetle epidemic destroyed most of the living trees. This is important information for land use planners and land managers. (722)

378. Transpiration losses may seriously deplete soil water and streamflow, especially during dry periods. A silicone antitranspirant applied to a timbered catchment in northern Idaho produced a 40 percent increase in streamflow and moisture depletion rates either less than or equal to those for a control catchment. The treatment is costly, but might be applied economically on municipal watersheds during very dry years. (50)

379. The amount and timing of water yields from forested watersheds may have serious downstream impacts. Soil water depletion was measured on cut and uncut lodgepole pine plots in glacial soils of northeastern Utah. Results indicate annual water yield increases up to 11 centimeters on well drained clearcut sites for several years thereafter until regrowth is well established. The study provides additional evidence that timber harvesting can increase water yields. (100)

380. Lack of knowledge about effects of timber harvest upon snowmelt in the Sierra Nevada has sometimes resulted in poor prediction of streamflow with resultant loss of water and hydroelectric power from reservoirs in California. Timber harvests are now being designed to change snowmelt to affect streamflow in a predictable manner. As a result, the time of delivery of water to streams can be predicted. (135)

381. A method is needed by government and private agencies engaged in streamflow forecasting for estimating snow water content from remote sites such as wilderness areas, without occupying the site. Lack of hydrologic data from such areas results in loss of millions of dollars in income annually from loss of hydroelectric power production because of inadequate operation of reservoirs downstream from such sites. A formula has been developed with which snow density may be obtained from solar radiation reflectivity (albedo) measured from aircraft flying over remote areas. This system will be of value to federal, State, and municipal water agencies and to private hydroelectric power companies. (118)

382. Inaccurate streamflow forecasts frequently occur because of a lack of information about the "ripeness," or wetness, of snowpacks under forested and open conditions. Timber harvests change the time of melt and thus wetness of snowpacks. A microwave system for measurement of snowpack "wetness" has been developed and is undergoing testing in California. The technique, which uses satellite telemetry for data gathering, is based on the attenuation of a microwave beam in transmission through snow. (116)

383. Evapotranspiration is the principal form of water loss from vegetated watersheds, but the relative losses by different species has been difficult to quantify. An inexpensive, efficient system for measuring plant-atmosphere gas exchange has been devised and used to measure transpiration from potted plants but is adaptable for measuring other gas exchanges. The system's versatility should lead to wide application in plant-atmosphere gas exchange investigations. (52)

384. Transpiration measurement of individual plants requires precise regulation of the temperature in plant enclosures. Available regulators are fairly expensive. A simple, inexpensive temperature controller utilizing thermistors has been devised. The unit will have wide application in studies requiring precise temperature control. (51)

385. Results from experiments at the Coweeta Hydrologic Laboratory are summarized in models for estimating the annual increase in water yield. Timing of the increased flow from watersheds depends on the magnitude of the increase, but results consistently show that much of the increase appears in the low-flow season. Although some increase in nutrient export occurs from forest cuttings and species conversions, the increase is well within current drinking-water standards. These facts should be used by watershed managers to achieve water resource objectives. (69)

386. Clearing forest land interrupts the hydrologic balance. Experimental cuttings on two hardwood forested watersheds in New England increased annual streamflow as much as 41 percent. Most of the increase occurred in summer and early autumn when additional streamflow is most needed. Within 4 years after complete forest clearing, revegetation caused the annual increases to almost disappear. Rotation cuttings will be necessary to maintain the increased volumes of water over time. (96)

387. The potential for possible damage to site and water quality from clearcutting has prompted various studies. Alternate strips were clearcut on a mountainous watershed in New Hampshire in 1970. Streamflow increased 54 and 23 percent for the first and second growing seasons after cutting. Electrical conductivity rose up to 30 percent due to increased leaching of ions from cut strips, but stream temperature, pH, and turbidity showed only minor changes. Increased ion output was greatest for NO_3 and Ca, but values were well below those for conventional clearcuts in the White Mountains. Management options may permit making clearcuts giving significant water yield increases but with minimal environmental impact. (93,94,95)

388. The New England hurricane of 1938 uprooted or broke off vast numbers of trees in watersheds of the Connecticut and Merrimack Rivers. Annual flow in both rivers increased about 5 inches during the first year after the hurricane. Another 5 inches of increased flow occurred at diminishing rates during the next 2 or 3 years. At least half of these flow increases occurred in July, August, and September when streams normally are at the lowest levels of the year. There was no evidence of increased flow 5 years after the hurricane when forest regrowth was well underway. And there is no evidence that forest cutting, as presently practiced in the eastern United States, has measurably increased the flow in larger streams. (126)

389. Much weather information useful to foresters is collected but not published. Analyzing 10 years of unpublished information at Elkins, West Virginia showed that measurable rain can be expected every third day, with half of the storms starting between midnight and 7 a.m. Rainy weather seldom persists for longer than a week and rainless weather never for more than 2 weeks. These results also are valuable to local interests in commerce and agriculture and they always attract notice among the general public. (129)

390. Published records of streamflow may provide a huge data base at little or no cost for evaluating long-term effects of land use on water resources. Analysis of early streamflow records in Massachusetts suggests that gradual afforestation has, since 1900, decreased annual streamflow about 1 1/2 inches in Massachusetts tributaries to the Merrimack River. This analysis reinforces evidence from more costly experimental watersheds that streamflow in the eastern hardwood region decreases with afforestation. (127)

391. Water demand in semiarid areas usually exceeds the readily available supply. Snowpack management can improve water yields from productive alpine areas. Snowfences, properly constructed and positioned, effectively trap blowing snow. The accumulative snow increases summer streamflow and the amount of available water. Fences also control drifting snow on highways and in avalanche-prone areas. (117)

392. It is desirable for the research hydrologist to periodically pull together and organize all information which has been presented in individual articles, papers, and notes in a variety of publications or is unpublished, and make this information available to land managers. Detailed status of knowledge summaries have bee prepared for each vegetation type in the Rocky Mountains to provide information on (1) what is known about the hydrology of the principal vegetation zones and (2) how this knowledge can best be applied to meet multiresource management objectives. This document provides the busy administrator who doesn't have the time to read the detailed reports with a

general overview and evaluation of the status of hydrologic knowledge for each major vegetative type. (110)

393. The current status of our knowledge of watershed management in the Rocky Mountains subalpine zone is presented in a recent document. Simulation models developed for subalpine hydrologic systems are described. From the review of past research, watershed management guidelines have been developed to answer the question "to what extent are we now able to recommend forest management practices to improve water yield, and still maintain acceptable water quality, quantity, and timing?" This information provides the land manager in the Rocky Mountains with the background needed for implementing watershed management principles into land use planning, and the tools to evaluate hydrologic changes resulting from different management alternatives. (111)

394. Conflicts between land use and the environment in the subalpine forest zone cannot be resolved without objective multiresource analysis, which accounts for both primary resource responses and their interactions. Simulation models developed to predict the short term effects of timber harvesting on snowmelt and water yield have been expanded to determine the long term interactions between water and timber resources with regard to different silvicultural systems in old growth subalpine forests. The largest increase in water yield occurs when about 40 percent of the watershed is harvested in small clearcut patches. The land manager now has a planning tool designed to simulate the probable hydrologic changes resulting from different timber harvesting practices in the Central Rocky Mountains for both short- and long-term planning intervals. (112)

395. The shortage of water in the arid Southwest has stimulated research on the effects of land management practices on water yield from snow. This report documents snowmelt runoff efficiencies for several experimental watersheds in various Arizona locales where snowmelt water yield is a significant contributor to the annual water yield budget. The basic snowmelt runoff efficiency data and empirically identified inventory-prediction variables presented would be applicable to most of the ponderosa pine forests in the Southwest. (136)

396. For assessing environmental impact and other effects of forest cutting, forest managers need reliable models on which to base predictions. Analysis of the biologic and hydrologic processes suggests a more logical and general non-linear model than the simple linear one previously used. This general non-linear model improved predictions when fitted to 22 water yield experiments in the Appalachian highlands. These results advance the scientific basis for predicting water yields since the general form is flexible enough so that only local estimates of parameter values (and non new curve forms) will be required. (119)

Managing, rehabilitating, and improving watersheds

397. Installing soil moisture access tubes in stony and bouldery soils is difficult and can be expensive in remote or inaccessible areas. In northern Idaho, a displacing device was used to provide good contact between access tubes and soil. The method is inexpensive, causes little disturbance to the surroundings, and allows relatively easy access to remote study areas. (149)

398. The magnitude of disturbance of alpine grazing lands is rapidly increasing due to industrial and recreational developments. Revegetation of these disturbed lands is urgently needed for watershed protection and forage production. Revegetation trials in southern Montana have shown that native species provide better long-term vegetative cover, but some introduced species give quicker initial growth. Combined plantings provide both rapid and lasting revegetation. (53)

399. The rehabilitation of surface-mined semi-arid lands presents many problems. Research at the Decker coal mine in southeastern Montana indicates several treatments that yield grass stands capable of protecting spoil materials against either water or wind erosion. Topdressing, fertilization, and irrigation have proven beneficial. Second year production was greater from native grasses than from introduced species. Land managers will use this knowledge in rehabilitation efforts. (37)

400. Acid mining wastes are difficult to revegetate and commonly are the source of soil erosion and severe stream pollution. Results of 2 years of revegetation research on acid mining wastes in central Idaho are described. Three types of main plots are used, each containing 12 treatments. The treatments are evaluated in terms of both vegetative production and ground cover, and vegetative species are evaluated in terms of their density and persistence under different treatment conditions. Coupled with a liming and fertilization program, topdressing of acid mining wastes with selected overburden materials appears to be a highly desirable revegetation practice. (33)

401. The hydrology, revegetation, and rehabilitation of fragile disturbed lands at high elevations presents special problems. Surface mine rehabilitation research underway in southern Montana includes techniques to achieve acid drainage abatement, vegetation establishment, and improved visual impacts. Related research is on plant species adaptability, plant-soil-water relations, microclimatic analysis, and photosynthetic efficiency of native-alpine plants. These studies will enable broad spectrum establishment of stable, attractive, rehabilitated lands that produce good quality drainage water. (101)

402. Estimating plant production accurately in annual plant communities is a time consuming task. An annual plant community can be sampled with minimum sample variation by using a two-stage procedure for estimating herbage yield. The analysis was done for a simulated population of *Bromus mollis* (soft chess) and should work reasonably well with other annual plant populations if used with prudence. This procedure should be useful for researchers and land managers interested in sampling herbage yield of annual plants. (122)

403. About 25,000 acres of stagnant ponderosa pine forest east of the Cascade Range in Washington and Oregon are thinned each year. A study was made on the effects of thinning to spacings of 12, 15, 18, and 21 feet on growth rate and water use by residual trees. Soil moisture depletion from heavily thinned plots averaged 3.3 inches less than from control plots during the first three summers after thinning. Tree growth was most rapid in the stand thinned to 15-foot spacing. Managers of these forest stands can vary thinning intensity to meet stated objectives. (89)

404. Good wind flow descriptions in remote areas are useful but difficult to obtain. An analysis has been developed which retains past wind speed information by computing the average speed for a small increment of travel and storage by speed and direction class. Low power requirements enable inexpensive bimonthly data collection. (75)

405. Artificial regeneration of harsh sites east of the Cascades is difficult. In small experimental field plantings near We-

natchee, Washington, survival of Douglas-fir 2-0 seedlings increased from 45 to 92 percent after soil fumigation with methyl bromide, and vigor of both Douglas-fir and ponderosa pine seedlings improved. Biotic factors may be restricting conifer seedling development on these harsh sites. (106)

406. A large wildfire in 1970 produced greatly disturbed soils on upper elevation slopes in north central Washington. A study was initiated to test the ability of a large number of plant species to become established on sites representing 926 acres of firelines. Later orchard grass, Drummond timothy, perennial ryegrass, Manchar smooth brome, and tall fescue were the best adapted species. A starter fertilizer treatment was essential for successful plantings. Managers can apply this information to similar site conditions. (105)

407. Nitrogen and sulphur levels are commonly low in forest and range soils of eastern Oregon and Washington and fertilization often helps in establishing new vegetation. Sulphur coated urea was one of several treatments applied to three regionally important soils, and orchard grass was used as a test crop. Yield response varied among the three soils, but the sulphur in sulphur coated urea was available in sufficient amounts to be of acceptable fertilizer value. Slow release nitrogen fertilizer plus added benefit of sulphur makes sulphur coated urea a useful fertilizer for certain forest and range soils of eastern Oregon and Washington. (103)

408. Environmentally sensitive areas may require special protection. The impact of five traditional and advanced logging systems on soil disturbance, erosion, and understory vegetation was compared under post-fire salvage conditions on the east slope of the Cascade Mountains. Traditional systems included tractor skidding over bare ground and cable skidding. Advanced systems included skyline, helicopter, and tractor skidding over snow. Traditional systems caused more severe soil surface disturbance and consequent erosion and should be avoided for use on sites with high erosion potential. (104)

409. Forest managers need to know if road building, clearcutting, and burning influence the storm hydrograph. Based on six small watersheds in western Oregon, peak flows were increased significantly after road building but only when roads occupied at least 12 percent of the watershed. Clearcutting also changed the storm hydrograph of most streams. The maximum increase in stormflow was 16 ft. ^{3}/sec/mi^2 which occurred after 82 percent of a 175-acre watershed was clearcut. The design of culverts and bridges in areas must accomodate changes in peak flows caused by roads, but the changes caused by clearcuttings are not of sufficient magnitude to require significant design changes. (84)

410. Integration of research with management is needed to obtain best results in land use planning. A land use planning process was developed for Oregon's Bull Run Watershed in concert with research data from Bull Run Watershed and from the H. J. Andrews Experimental Forest. This example of active incorporation of research results in the land use planning process can serve as a planning guide. (77)

411. Future demand for southern pine products may affect water quality and reduce water yields. Water quality standards related to forest practices are being promulgated, but more information is needed to establish realistic criteria. Needed are the identification of sources and the quantification of pollutants, the development of predictive capability, and the definition of practical alternative forest management practices. Research can assist management to devise practices to help prevent the adoption of unwarranted restrictions. (146,147)

412. Sand bedload additions to trout streams have been assumed to reduce habitat quality and often result in costly control measures. Daily sand additions for 4 years to a Michigan trout stream increased stream gradient and width and decreased stream depth and total static volume of water. Streambed composition changed mostly to sand and major pool filling occurred. Effects of these changes on trout populations will permit evaluation of stream damage from bank erosion or on-site construction disturbances. (83)

413. Where many lakes occur, such as north-central Minnesota, the surface elevation of groundwater lakes can be used to draw water table contour maps. The specific conductance of lake water was used to separate groundwater lakes from perched lakes and devise areal water table maps. These maps can be useful in locating wells and waste disposal sites. (85)

414. A rapid method is needed for estimating streamflow responses over a range of forest management practices. The annual water balances of a mature oak-hickory forest, a clearcut oak-hickory forest, and a young pine plantation were simulated by the PROSPER ET Model. The model used actual environmental conditions at, and closely matched responses from, experimental watersheds at the Coweeta Hydrologic Laboratory. These successful simulations led to the integration of PROSPER into a more general model which should produce a useful research and land management tool. (141)

415. The hydrologic characteristics of the forest litter layer are central to understanding biotic and abiotic processes in the litter. A model was developed to predict water content and evaporative losses in the litter of a mixed deciduous forest. The model uses readily obtainable data. Simulated evaporation and litter water content over an 80-day period showed good agreement with experimental data. The model is useful in conjunction with litter decay and mineral cycling studies and can also be utilized in fire danger rating systems. (120)

416. The 1972 Amendments to the Federal Water Pollution Control Act require that non-point source pollution from forestry activities be controlled. Erosion, primarily from mechanical site preparation, roads, skid trails and logging decks, and fire are primary sources of sediments in streams. Cutting riparian vegetation may increase stream temperature, but increases can be controlled with buffer strips. Cutting can change the nutrient content of forest streams, but chemical changes have not degraded water for drinking purposes. Using existing information, sediment and other forms of pollution can be minimized by careful planning and supervision of management activities. (68)

417. Forest fertilization in the northeastern U.S. may increase markedly in the near future to help meet many non-wood production goals. Information is needed on the use of fertilizer to enhance vegetation and prevent soil erosion for improvement of recreation sites, wildlife areas, and watershed quality. Diagnostic techniques are needed to evaluate these specialized fertilizer requirements and environmental interactions, potential pollution hazards, and other side effects. (109)

418. Planning for monitoring results of experimental treatments in forests is a complex problem. Over 60 variables are required to characterize the physical aspects of the soil-plant-atmosphere system. Each of these may vary spatially, temporally, and as a result of treatment. Availability, cost, and opera-

tion of instruments and data-logging systems may place severe restrictions on achieving the desired results. This article should help forest scientists to make the difficult decisions involved in monitoring planning. (71)

419. There is an increasing demand for more and cleaner water. More than 20 years of research in forest hydrology at the Fernow Experimental Forest in West Virginia demonstrates that water yields can be increased by tree cutting, with little or no ill-consequence to water quality. Concern that diminished soil productivity and polluted water necessarily attend wood products harvest is shown to be unwarranted. It is not practical, however, to manage forest land for both sustained increased water yield and merchantable timber products in this area. (107)

420. An unfounded belief persists that harvesting timber threatens to eventually deplete forest soils. Present knowledge indicates conventional harvest practices on eastern hardwoods pose no threat to continued forest soil productivity. Additions to the soil nutrient capital by precipitation, rock weathering, and biological processes replace nutrients removed from the site by wood products harvest. Continuing assessment of soil fertility and tree nutrition should accompany shorter cutting rotations and more complete tree utilization. These results help to reassure forest resource managers and a public that is deeply concerned with environmental degradation. (128)

421. Passage of Public Law 92-500 introduced the vaguely defined concept of non-point pollution and called for State Laws to control it in forests. The virtual non-existence of overland flow in moist climate forests bears directly on the concept of non-point pollution as well as its control in forests. The false assumption of overland flow necessarily underplays elutriation while overplaying surface erosion as causes of damage to forest soil and water resources. Fuller understanding of how water passes from sky through forest soil to streams, coupled with ability to mathematically model this passage, must provide measures to control non-point pollution that are realistic as well as attainable. (90)

422. Extremely acid mine spoils are difficult to vegetate. When used with lime and N and P fertilizers, a mulch of shredded bark assisted successful establishment in eastern Kentucky of grasses and legumes on spoils of pH 2.2 to 3.5. The mulch reduced evaporation and maintained moisture in the limed 2–4 inch rooting zone. Without mulch, only a sparse grass cover was established and rehabilitation was not achieved. (38)

423. Relative survival and growth largely determine the suitability of tree and shrub species for planting on acid surface mine spoils. Fifty-five species were evaluated on two surface mine sites in eastern Kentucky. Four years after planting, three species of birch, three of olive shrubs, and several non-commercial tree and shrub species grew well on a range of sites. Both commercial and non-commercial species should be considered by managers to reforest and protect surface mine spoils. (26)

424. Most herbaceous plantings will not survive on spoils without amendments. Lime, fertilizer, and hardwood bark mulch were applied to four problem spoil areas in Pennsylvania. The plots were planted to red pine and seeded to a mixture of weeping lovegrass, K-31 tall fescue, and Korean lespedeza. The amendments did not aid red pine survival or benefit Korean lespedeza but helped in the establishment of weeping lovegrass, K-31 tall fescue, and volunteer vegetation. This study supports the need to apply amendments to vegetate mine spoils. (31)

425. In a study on three small watersheds near Baltimore, Maryland, water quality was improved but yield decreased when open land was converted to pine. Riparian vegetation removal improved water yield but reduced water quality. These results provide watershed managers with some guides to evaluate the effects of alternative forest operations on water quality. (62)

426. Municipalities that own entire watersheds need to know the effects of alternative land management practices on water supply and quality. In a municipal watershed study at Newark, New Jersey, conversion of oak-hickory vegetation to grass increased water yield, with most of the additional flow yielded during the summer months. These results are useful to watershed managers, especially on municipal watersheds where the area available for water yield purposes is limited. (60)

427. Effective watershed management depends on knowing the source of water yield during different parts of the storm hydrograph. A simulated rainfall study on a 7.9 hectare watershed in central Pennsylvania showed that the rising limb of a storm hydrograph is caused by precipitation falling in and near the stream channel. Upper slope conditions control peak flow duration and the decline rate of the recession limb. This information assists watershed researchers in defining stormflow characteristics and managers in watershed planning. (63)

428. More information is needed concerning the effects of forest floor characteristics on the hydrologic cycle, herbage production, tree regeneration, and fire behavior. The mean weight and depth of the forest floor in Arizona ponderosa pine on sedimentary soils averaged 7.0 tons per acre and 1.0 inch in depth, with the greatest accumulation in the H layer. These values were similar to those previously found on soils developed from volcanic parent materials. The results from this study add to our ability to manage ponderosa pine forests in the arid Southwest. (73)

429. Cattle grazing and timber production, two major uses of forested lands, are often competitive. The presence of ponderosa pine in any density will decrease the beef gain potential or livestock carrying capacity. Beef gain potential was maximum at zero basal area and was one-third less when ponderosa pine was present at basal areas of 20 ft ²/ac. Physical relationships and the 1972 prices suggest that the combined economic value of grazing and saw log production would be maximum in tree stands having basal area of about 45 to 60 ft ²/acre. (59)

430. To effectively manage bunchgrass rangelands within the ponderosa pine type, more needs to be understood about its ecological base. This state of the art paper documents the available physical, biological, management and economic data of the Arizona ponderosa pine—bunchgrass range ecosystem. It provides a much needed source of information for land managers and will also serve as a background for decisions concerning possible new research directions. (54)

431. Wildland managers need current information about the relative and absolute importances of the various uses and demands on pinyon-juniper woodlands, as these have changed considerably of late. Past management of pinyon-juniper woodlands gave highest priority to individual specific uses such as grazing, wildlife, and water production. Future management should result in a shifting mosaic of activities with each site managed over time for that needed product, product mix, or sequence of uses

for which it is best adapted. These findings can be applied to increase efficient use of our wildland resources. (55)

432. Ecotypic differentiation as a response to climatic conditions was studied in an adaptable grass species, *Sitanion hystrix*. The study indicates that the primary factors which influence morphological and production characteristics may be more numerous or complex than those which influence phenology: under uniform conditions, plants from warm, dry habitats flowered early and had low dry matter production; plants from cool, wet habitats flowered early and had relatively high dry matter production. The study provides valuable information about a common species widely distributed throughout the western United States. (56)

433. Land managers have expressed a need for better methods to more effectively utilize resource response information in the land use planning process. Results from watershed treatment studies in the pinyon-juniper type are examined in light of their impacts on multiple uses of the land. They show conversions of pinyon-juniper to grass can only be justified economically in cases where range improvement benefits are likely to be substantial. Conclusions generally apply to all pinyon-juniper lands in Arizona, New Mexico, Utah, and Colorado. (57,58)

434. Ponderosa pine forests occupy more than 1,650,000 acres in the Salt-Verde River Basin and supply nearly half of the total runoff in the basin. Yields of timber, herbage, and water under past management and under new experimental land treatments are reported, along with information about effects on wildlife values, esthetics, flood and sedimentation hazards, and water quality. Overall, the results of these studies now provide southwestern pine managers the means for realizing substantial improvements in the information upon which land management decisions are based. (48)

435. One of the major problems in land-use and watershed planning is in predicting what effects management practices would have on soil erosion and transport. A numerical computer model is presented that simulates the physical process systems by which water and sediment are moved overland and in stream channels. The model predicts water and sediment hydrographs and yields at downstream locations resulting from the overland flows produced by individual storms. Initial tests on ponderosa pine and pinyon-juniper watersheds have been very encouraging. This model represents a major advance in modeling the erosion process. (133,134)

436. With the complexity of managing today's wildlands, land managers have expressed a need for better methods to more effectively utilize resource response information in the land use planning process. Results from watershed treatment studies have been used to develop preliminary resource response models which will help land managers judge which alternatives best meet their objectives. These models are applicable to many planning situations, and specific information derived from such applications is being used in management decisions for much of the ponderosa pine forest land in the Southwest. Economic analysis shows that proper management can benefit all natural resources on ponderosa pine lands, even when environmental constraints are considered. (47)

437. An important aspect of runoff modeling is to solve the unsteady, gradually-varied flow problem effectively for various flow conditions. A simple numerical model for both overland and channel water routing is presented. The model includes the effects of rainfall on flow resistance and simulates hydrographs which agree very well with experimental results for both constant and variable rainfall cases. This numerical model eliminates the unstable condition often found in cases of supercritical flow and the requirement of downstream boundary conditions which are usually not available, and minimizes the complexities of applying a model to a large scale area. (113,114)

438. Fourwing saltbush is a valuable shrub that provides forage for domestic livestock, food and cover for wildlife, and protects soil from wind and water erosion in semiarid areas. These features are beneficial for coal mine spoil reclamation efforts. Soil microorganisms are lacking in coal mine spoils. Inoculation of fourwing saltbush seedlings with *Glomus mosseae* improved transplanting success in areas receiving less than 250mm of precipitation in New Mexico coal mine spoils. (41)

439. Coal spoils are deficient in plant nutrients and organic matter. Emergence and early growth of mountain rye and fourwing saltbush were studied in untreated 3-year old mine spoils, and in spoils to which organic matter or fertilizer had been added under greenhouse conditions. Emergence and growth were satisfactory from untreated spoils; adding amendments had no effect on seedling emergence or early growth. (43)

440. In low rainfall areas, supplemental water may be needed for vegetative establishment. Paraffin and polyethylene catchments were tested and found equally effective in harvesting runoff water from small storms (less than 0.45 inch). Two-month-old fourwing saltbush transplants grew more during their first growing season with this increased moisture. These methods of water harvesting were tested further on surface coal mine spoils in western New Mexico. Siberian peashrub transplants showed better vigor, and soil moisture measurements were about 20 percent greater under the treated plots. Information can be useful to those establishing shrubs on difficult sites. (44)

441. Disturbed areas, such as coal spoil banks, new roadcuts, etc., are increasing in the Southwest, and revegetating these areas is difficult in low rainfall zones. A new publication summarizes our research knowledge for establishing fourwing saltbush and alkali sacaton on harsh sites where rainfall is less than 10 inches per year. This information should be useful to land managers responsible for stabilizing disturbed areas. (42)

442. Prescribed burning in chaparral is one alternative for converting from shrubs to grass. The effects of such fires on the properties of the soil must be understood in order to minimize erosion. Relatively cool fires caused water repellency in the surface layer, while hot fires produced repellence at a greater depth. Under hot fires, however, the surface layer was rendered completely wettable. The volatilized material causing water repellence is almost completely lost above 270°C. Hot fires are more successful in killing shrubs, and are also best in terms of increasing soil wettability which would minimize erosive runoff. (132)

443. Feasibility of increasing water yield by chaparral conversion in the Southwest depends on how much water can be produced and how conversion affects other resources. Twenty years of research on small experimental watersheds show that conversion to grass substantially increases water yield and forage for livestock. If treatment areas are kept small and interspersed with native chaparral, wildlife habitat and esthetic values are preserved. While most treatment practices temporarily increase

erosion, conversion should decrease erosion over the long run. Constraints restrict conversion to about 21 percent of the chaparral, which, if converted and maintained in grass, would increase in Arizona's surface water supply by about 155,000 acre-feet each year. (91)

444. Bluegrass meadows in the Black Hills have long been subjected to intensive livestock grazing that has caused compaction of soil and possible increased rate of water runoff leading to flash flooding. Research results indicate that more than 1 year of full protection from livestock grazing is necessary for significant soil recovery and reduced summer runoff. Consequently, bluegrass meadows must be rested from use by livestock at least one full season in order to accomplish any change in soil porosity and increased water infiltration to reduce summer runoff in the Black Hills. (123)

445. Changes in shallow groundwater due to surface mining are a major concern in the Wyodak outcrop area in Wyoming because of the exceptional thickness of the coal beds. Water levels, movement, and storage before and after mining and movement in the resulting spoil material are being measured through the use of a network of wells to the top of the coal, through the coal and below the coal. These data will alert land managers, particularly livestock managers, of possible water level changes due to nearby surface mining operations. (35)

446. In order to establish plants on coal mine spoils, the properties of the spoils must be understood. Results of standard agricultural analysis for the coal spoils from the Belle Ayr South Mine near Gillette, Wyo. did not show any limiting soil characteristic that may interfere with normal plant growth. Thus favorable response is anticipated from these spoils as a growing medium. (39)

447. The removal of a 100-foot thick strata 200 feet below the surface of a 500-sq. mile area will drastically alter the landscape, particularly when there now are no real insights in the description of the topographic features. Mapping the Powder River Basin in Wyoming and Montana will provide the initial key to detect and understand subtle as well as more obvious topographic distinctions, variations, and their trends on a regional basis by quantitative data rather than by qualitative assessments. This technique will provide a scientific rationale and understanding to the regional geomorphic trends and their ecologic implications to assist managers responsible for reclamation and management of the lands after the mining is done. (440)

448. Thermistor temperature measurements are non-linear, especially over a range of tens of degrees. This precludes recording results on strip charts and magnetic tape, as well as analog computation involving thermistor output. An electronic system was developed to produce linear results suitable for recording and computation. (131)

449. Since 1970, the number of snow avalanche fatalities has doubled. Casualties can be minimized by alerting the public to dangerous conditions through a warning system. An effective warning system requires accurate prediction, for which snow slope deformation, a precursor to avalanche release, may be useful. A gage to measure deformation was developed and installed in Colorado. Such measurements may facilitate prediction of avalanches. (102,137,148)

450. Previously there has been no way to predict the profile of snowdrifts in certain terrain. A regression model, developed to predict snowdrift profiles using only topographic data, closely duplicated observed drift profiles in Wyoming and Colorado. The Wyoming Highway Department is using this analysis to design drift-free roads. Other applications include reshaping strip-mined terrain to maximize snowfall retention to conserve moisture for revegetation. (152)

451. Snow research and management often require measurements of snow transport. A simple, inexpensive, and effective instrument for recording amounts of blowing snow was developed and tested in Wyoming. The record from the snow gage can be used to 1) determine weather conditions during drifting, 2) identify sources of blowing snow, 3) compare drifting at different sites, and 4) estimate seasonal transport. (99)

452. Quantification of the transport and evaporation of blowing snow is necessary for its efficient and economical control. A mathematical model was developed to estimate transport and evaporation of blowing snow. Predictions agree well with snow accumulations measured in Wyoming, and indicate that a significant portion of snow evaporates in-transit. The model can be used to assess effects of land management practices on blowing snow and to evaluate the feasibility of snow management practices. (143)

453. Efficient monitoring of the productivity of forage crops on shrublands of the western U.S. is needed for their proper management. Electronic capacitance meters give rapid, accurate, and non-destructive estimates of herbage yields. A double sampling technique utilizing the meter was described and tested on sagebrush, winterfat, and saltbush ranges in Wyoming, Utah, Colorado, and California. The method gave reliable yield estimates and the meter reduced sampling costs. (121)

454. Knowledge of the hydrology of sagebrush lands in windswept environments is needed so that better management practices can be developed to improve and protect them. In south-central Wyoming, causes and consequences of streamflow over the snow surface in channels filled with wind-drifted snow were described. This phenomenon significantly affects water yield efficiency, flood flows, conveyance losses, groundwater recharge, and sediment yields. (139)

455. Intensive recreational use of forested areas such as for skiing, may severely affect sensitive ecosystems. Monitoring the chemistry of associated streams provides a means of testing the impacts of ski area development. Road salting severely affected water quality. Sewage disposal affected inorganic water quality to a minor degree. Poma lift construction and light tree removal had no measurable effects on the water quality parameters measured. These data provide the basis for estimating impacts of a number of activities associated with ski area development. (81)

456. Research has shown that greater quantities of snow accumulate in small clearings or natural openings than under closed forest stands due to elimination of the interception loss from trees and subsequent evaporation. Research shows this explanation is incomplete and that distribution pattern rather than total snow accumulation is the main factor affected. Prevailing airflows will ultimately control the snow distribution in openings. Maximum accumulation is near the center of small clearings where airflow allows deposition. Minimum accumulation is along the leeward border. The advantages of increased accumulation and melt in openings created by logging must be weighed against the decreases in snow along downwind borders and possible detrimental effects on growth of trees along these borders. (78)

457. Water yields are important in the pine zone of the Colorado Front Range. However, they are comparatively small in contrast to yields from the high-altitude subalpine forests. Most of the soils, derived from granites, are coarse textured and have a relatively low productive capacity. These soils are potentially erosive once the protective vegetation is disturbed by poor logging practices, overgrazing, and uncontrolled urbanization. Watershed management practices can be expected to provide practical alternatives for increasing water supplies. (79)

458. Runoff and sediment production are important considerations in multiple use management of mountain rangelands. Eleven years of records from the Black Mesa Experimental Area show suspended sediment concentrations after summer storms to be as much as six times as great as those sampled during snowmelt, but total yields were small during the summer because of the small volume of flow. Based on current erosion classification schemes, proper grazing management on western Colorado mountain grasslands seems to result in little more than "geologic erosion". (76)

459. Lodgepole pine forests are important water source areas in the West. The proportion of water yield to precipitation is high because of the cold climates, short growing season, and accumulation of an overwinter snowpeak. Water quality is excellent but subject to damage by road construction. Water yield can be increased by appropriate timber harvesting techniques, but the larger amounts flow off during the natural high water season. Land managers must become increasingly aware of their influence upon water and work more closely with those concerned with water resources. (92)

460. To ensure renewal of forest resources, special logging practices must be implemented. Old-growth southwestern mixed conifer stands commonly have advance regeneration, but one-cut overstory removal with slash piling typically has destroyed most of it. Damage to advance regeneration was examined in an Arizona watershed where special care was taken to avoid damage. The selection method led to less destruction than one-cut overstory removal. Logging modifications are recommended to further reduce damage. (82)

461. Effective management of watersheds requires an understanding of their geomorphology. Criteria were developed and utilized for several watersheds in Arizona and Colorado to determine if a watershed is in dynamic equilibrium. Landform development at these sites was fully described. Geomorphology can aid in interpreting treatment efforts and in predicting if planned actions will work with or against natural forces. This approach can save time and money. (86)

IMPROVING ENGINEERING SYSTEMS

462. Economical logging in steep terrain with cable systems is very dependent on proper planning. Research has provided simple programs for desk-top computers that tell the logging manager where to set up their yarding system on a given harvesting site and determine load carrying capabilities for a variety of alternative settings and cable systems. These programs, now in wide use, eliminate costly mistakes in steep terrain logging operations. (1217)

463. Although cable logging was used in the Appalachians in the past, tractor logging is now the most commonly used method of extracting logs. Tractor logging is the cheapest way to log but is also one of the most damaging to the environment. Cable logging is being introduced again through several experimental studies to evaluate costs and to reduce environmental impacts and costs. From an environmental standpoint, cable logging is more acceptable. (1226)

464. Forest managers require production rates and costs for alternative logging methods and harvesting operations. This is particularly true in steep terrain. Several loggings systems including high-lead, skyline, balloon, and helicopter were studied in the logging of old growth Douglas-fir. Results provide forest managers with a means for estimating direct yarding costs which are a significant part of the total logging costs. (1219)

465. The Eastern United States has 32 million acres of northern hardwoods which are predominantly overstocked with saplings and poles while understocked with sawtimber. These stands require thinning if we are to realize their fullest quality and economic potential. A recently completed study shows that the right combinations of available highly sophisticated equipment can harvest thinnings profitably in stands considered unmerchantable with more conventional logging methods. This study provides guidelines by which a majority of these dense hardwood stands can be thinned economically and provide for maximum growth and quality of our valuable northern hardwoods species. (1214)

466. Rising prices of fuels are forcing industry to seek alternative sources of energy for manufacturing processes. A simple graphical means of estimating and comparing the cost of using wood and other residues with more conventional fuels was developed. Wide use of this technique has been made to assist industry in evaluating the potential of using wood residues as a substitute fuel. (1211)

FOREST RESOURCES EVALUATION

Resource Inventories

467. Current forest resource statistics are necessary to adequately monitor change. These reports present the results of the latest forest surveys of the Blue Mountain area in Oregon and Okanogan County, Washington; along with an analysis of the trends since the last survey. The data presented are regarded as essential by policymakers in the public and private sectors of the economy. (1040,1041)

468. Forest resource statistics for coastal or interior Alaska are either not available or they are dated. These reports present current information for southeast Alaska and the Tanan and Copper River inventory units of interior Alaska. The data presented will be helpful to resource managers and policymakers. (1050,1051,1052)

469. Information on forest area is a vital part of a timber inventory of a State. The 1974 survey of Iowa's woodlands shows a commercial forest area of 1,458,700 acres, about 4 percent of the State's total land area. Area in 1974 cannot be compared directly with that of the 1954 survey because of changes in definitions and survey techniques. Noncommercial forest land amounted to 102,600 acres in 1974. This information can be used by persons who grow, utilize, plan, and analyze the timber resource. (1049)

470. Because many factors affect and change the timber resources, up-to-date forest surveys are needed to determine current conditions, evaluate trends, and assess the outlook for the resource. Heavy utilization of pine and a lag in controlled regeneration have reinforced the strong trend toward hardwood dominance in North Carolina as a whole. In the Piedmont, however, the pine inventory has exhibited an upward turn. Even though volume is increasing, the amount of timber land has been declining due to renewed agricultural activity and continued urban encroachment. These findings will be useful to resource planners in North Carolina and the South. (1046,1055,1056,1057,1064)

471. Current estimates of forest resources by State and county are generally not available because of the 10-year interval between ground surveys. Through updating techniques, current estimates have been developed for Alabama and Arkansas. These data can be used in monitoring change and in formulating management plans. (1038,1039)

472. Because many factors affect and change the timber resources, up-to-date forest surveys are needed to determine current conditions, evaluate trends, and assess the outlook for the resource. A series of reports, based on the most recent survey (1974) of Louisiana, shows that forest area had declined 9 percent since the 1964 inventory, and now stands at 14.5 million acres. Softwood volume increased 31 percent, while hardwood had a 7 percent loss. The results should help in the formulation of forestry policies and programs for Louisiana. (1047,1059,-1060,1061)

473. Detailed resource information is needed when making subregional management plans. A recent report presents 36 tables, by county, for various area and volume strata. Such data are regarded as essential operating statistics by numerous forest industries and public agencies. (1048)

474. Changing land use patterns favoring agriculture are adversely affecting the forest resource situation in the lower Mississippi valley. The valley's land base is not only shrinking in size, but it is also declining in terms of inherent productivity. There is an urgent need for accelerating management efforts in the potentially productive loessial region that adjoins the valley. These findings should aid decisionmaking in the private forestry sector and help policymakers in formulating public forestry programs. (1062)

475. The Southern hardwood industry has become increasingly concerned about the long-term supply of trees suitable for industrial use. A new appraisal shows that the hardwood sawtimber inventory in the South is increasing. It now totals more than 300 billion board feet (International 1/4 inch rule). The total estimate represents a gain of 15 percent since 1953. Total acreage of commercial forest land, however, is about the same now as it was in 1953. These results should provide a sound basis for developing and revising public and private forest policies. (1063)

476. Little has been done to evaluate management and marketing policies for increased timber production on tax-forfeited lands in Minnesota. Preliminary findings indicate that tax-forfeited acreage under county administration decreased 18 percent in the last 10 years. Study of marketing and management policies on county lands is basic to determination of the role of these lands in meeting future demand for timber products and recreation activities. (1058)

477. Retired crop land no longer can be relied upon as a major source of new pineland in Georgia. Activities that initiated and stimulated shifts of lands to and from pines were identified by examining previous and current trends in land use. Suggested are five courses of action that will keep one-third of the land in Georgia as pineland: reforest harvested stands to full stocking; delay harvest of loblolly and slash pine stands at least until age 30; reduce thinning and related TSI in pine stands; use TSI primarily to convert oak-pine stands to pine; stop converting natural stands of longleaf, shortleaf, pond, and Virginia pine to loblolly and slash pine. (1043)

478. An increasing demand for forest products and shrinking land base emphasize the need for achieving the full biological potential on forested acres. For ecosystems east of the Mississippi, the potential for loblolly pine is estimated to be 2 billion cu. ft. of net annual growth per year; for slash pine it is 1 billion cu. ft. And, without adding to the ecosystems, the average rate of removals in cu. ft. can be doubled in about 30 years. To achieve this potential for loblolly and slash pines, one of the most important actions is reforestation at full stocking. In addition, for slash pine, delaying harvesting until about age 30 is required. (1042,1044)

Utilization and Production

479. A major problem of the Forest Survey is determining the drain on forest resources and keeping up with the number, size, and location of primary forest industries. Harvest of east Texas roundwood totaled 456 million cubic feet. Pulpwood, sawlogs, and veneer logs made up over 98 percent of the harvest. A total of 202 wood-using plants were in operation. Similar information is available for Ohio, Iowa, Washington, and Oregon. These data are of value to a wide range of interests, including industry, wholesalers, land managers, land use planners and development councils. (1066,1071,1076,1078,1079)

480. Pulpwood production figures are of high interest to forest industry managers and land owners in the East. In 1974, pulpwood production was 62.8 million cords. Although production in some states declined, every region showed a production advance except the Central States which showed a small decline. This information is widely used by both private and government organizations. (1067,1068,1070,1072,1073,1074)

481. Pulpwood prices differ according to location, type of delivery, species, and form. Record high prices were experienced throughout the 12 Southern States. Roundwood prices rose 19 percent in the mid South, and 17 percent in the Southeast. These data could provide a basis for projecting future price trends and can be used as a guide for buying and selling pulpwood. (1065,1069)

482. During a resurvey of New Jersey's timber resources, a study measured the losses of wood fiber attributable to clearing of forest land. An estimated 120 million cubic feet of growing stock were destroyed on the 164,000 acres of commercial forest land cleared between 1955 and 1971. Most of the recovered industrial wood fiber came from forest lands converted to agricultural use, and most of the recovered firewood came from homebuilding sites. By recovering and using greater quantities of wood during land-clearing operations, the Nation's timber supply can be extended. (475)

483. Soil scientists and forest land managers are often unable to communicate effectively and the expertise of the soil scientist

may not be used most effectively in management. Recent changes in policy and legal context, in amount and kind of planning and analysis for management, and advancement in planning technology are described. A general framework for land management planning has been developed in which component activities are sketched and the role of the soil scientist is described. By using this framework, soil scientists can better relate to land management and to other supporting scientific disciplines, and managers better able to effectively use fundamental soils information. (1077)

Inventory and Analysis Techniques

484. Sampling efficiency is an important consideration in the planning of a forest resource inventory. Theoretical analyses often go unheeded until they are demonstrated in fact. This study was an empirical analysis to contrast several sampling methods in eastern forest conditions. The results show that Sampling with Partial Replacement (SPR) is more than twice as efficient as complete remeasurement for estimating current volume. The efficiency of SPR for area estimators varies from more than twice as efficient in situations of very little area change to eight times as efficient in regions of significant change in the land use pattern. Results of this study are valuable inputs to planners of future forest inventories for eastern forests. (1082)

485. Owner attitudes, especially in the private sector, quite often determine the availability of timber and timber land for any kind of use. In three southern New England States and the States of Delaware and New Jersey, these owners have been sampled to obtain insight into the characteristics and objectives of this ownership group. In Delaware and New Jersey, the private owners indicated that they would or had allowed harvesting on their holdings. In southern New England, on the other hand, an overwhelming majority held timber land for reasons other than monetary or material gain. The results of these studies will be useful to planners and other decisionmakers who are interested in the forest and related resources of the Northeast. (1053,1054,1088)

486. The large number of tree species comprising Appalachian hardwood forests and their varying ecological requirements appear to result in more-or-less distinct associations on sites of given quality. Does the presence of certain associations prove useful in predicting site quality? Using data collected at over 100 sample locations, tree species occurrence was treated as dummy variables and related to oak site index. A procedure for easy field application of the method is presented. This system should prove useful also in other forests with a wide diversification of species. (1094)

487. A significant relation between species composition and oak site index was developed from forest survey data in West Virginia. The coefficient of determination and predictive value of individual plots, however, were low. Field use of the procedure is presented in a paper. The presence of certain associations might prove useful in predicting site quality, especially in an area such as the Appalachians where it is customary to evaluate sites in terms of oak site index, even when oak is not the primary species. (1095)

488. Future levels of timber supplies are of major concern to substantial areas of each of the Pacific Coast States. A recent study presents, in detail, the projections which were used in the Forest Service report, "The Outlook for Timber in the United States." The localized projections will enable the individual States to view the prospects for future timber supplies and to consider the possible consequences. (1085)

489. Many people are concerned with determining future levels of employment in the forest products industry. In a recent publication, relationships are developed which provide a basis for translating future levels of wood supply and use into direct forest industrial employment. Historical trends in employment are shown; these provide a basis for extrapolating employment into the future. The report also shows seasonal variations in employment by industry sector. (1093)

490. Net volume per tree estimates are often difficult to obtain. A paper presents an equation and tables of coefficients to determine merchantable tree volume in both cubic feet and board feet, for use with a digital computer or modern electronic desk calculator. The only data needed are species, d.b.h. and site index. The results should be of interest to consulting forester, industrial forester and others interested in volume determination. (1086)

491. Most of the forest-range environment in southwest Louisiana is grazed by livestock—mainly cattle. Grazing is most widespread on the holding of forest products industries. This may reflect a new trend in the South. Certainly, the increasing application of even-age forestry on industry lands is favorable to a dual management system of raising beef and growing timber. Herbage production from southwest Louisiana's forest ranges totals 2 million tons annually. The longleaf-pine ecosystem is the most productive yielding 1,529 pounds per acre. The other ecosystems that characterize pine sites average some 800 pounds per acre with the lowland forest-range ecosystem being least productive. The average for all inventoried ecosystems is 895 pounds per acre. These findings should aid decision making in the private forestry sector and help policymakers in formulating for long-range public forestry programs. (1091)

492. We need to know how and if low resolution remote sensor data from ERTS (Earth Resources Technology Satellite) is an asset for natural renewable resources inventories. General vegetation classes such as conifer forest, deciduous forest, and grassland can be classified with 85 to 95 percent accuracy using either photo interpretation or computer-assisted analysis. Classifications for kind of coniferous forest, kind of deciduous forest or kind of grassland could not be made with acceptable accuracy by either method. Forest disturbances from natural causes or human activity could be detected with 90 percent accuracy when ERTS imagery was compared with 6-year-old aerial photos. Stress in ponderosa pine from mountain pine beetle could not be detected. These results identify the use of ERTS imagery for a first level of stratification for renewable resources inventory on a regional basis. (1087)

493. Skylab (EREP) imagery had about five times improved resolution as compared to ERTS imagery. Therefore, we needed to determine if skylab data would be an asset for resources inventories. The color photography from the earth terrain camera (S190B) provided successful (90 percent accuracy) classifications of general vegetation classes. However, classifications of specific kinds of forests or grasslands was date, film type, and photo scale dependent. Color infrared photos from the S190B would improve classification. Mountain pine beetle infestations in ponderosa pine forests could not be detected on color-combined multiband black-and-white, normal-color, or color infrared

photographs (1:2.5 million in scale) from the S190A camera systems. These results can be used to correct for solar and atmospheric effects for analyzing satellite imagery. (1080)

494. Techniques to improve range resource management planning are needed. Aerial photographs, especially color infrared, provide range resource analysts a needed tool for inventory, evaluation, and monitoring of range resources. This includes satellite and hi-flight aircraft photography for mapping plant communities. It also includes use of low-level aircraft photography for identifying and estimating selected certain plant community components such as species identification and measurement of plant cover. (1090)

495. Improvement in techniques for inventory of forest lands is needed to assess the condition and change of those lands both continuously and periodically. Recent developments in use of aerial photographs, especially color infrared, have demonstrated increased accuracy in classifying forest land, providing estimates of species composition of forest stands, making estimates of standing timber volume, and assessing impacts of insect and disease in forest stands. Thermal scanners provide a valuable system for detecting and mapping forest fires. Color films are valuable for assessing air pollution effects, wind damage and other natural or man-caused forest depravations. (1092)

496. Nonindustrial private forest landowners hold a significant proportion of the nation's timber resource and the priorities of public programs designed to improve their management should be continually sharpened. Program managers are urged to first explicitly identify the goal they seek, then evaluate the performance of past public programs designed to achieve similar goals. Only through steps such as these can public assistance programs achieve the greatest goal accomplishment at the least cost. (1089)

497. Traditional statistical analyses are not applicable for the development of models to describe mortality or other similar responses that are dichotomous. The SCREEN computer program was developed to provide a statistically valid and efficient procedure for screening relationships between a dichotomous dependent variable and sets of explanatory independent variables. The program is applicable for a wide variety of analyses including evaluations of forest regeneration, diseases, cull volume in apparently sound trees, and patterns of habitat use by animals. (940)

498. Acquisition of timber inventory data is proceeding slowly because of the manual methods being used in many locations. Forest patterns or images on photographs and maps can be delineated, digitized, and stored by a variety of manual and automatic techniques. Investigation of a dozen different geographic information systems reflects a wide divergence in approaches. Comparisons indicate that the larger investments in computer mapping systems are most likely to have the lower inventory costs per acre. (1081)

499. Computerized methods for graphically presenting multidimensional data in two dimensions while retaining information from the original data would be of value in forest research. Recently, a general derivation was developed and a general computer program was prepared for performing the necessary computations and plots. The method can be applied routinely by using the computer program to expose features of multidimensional data which might not be discovered using less sophisticated methods. The capabilities provided will be of particular use in the fields of genetics and taxonomy. (955)

BETTERING SILVICULTURAL SYSTEMS

Natural regeneration

500. Frost heaving, and both low and high surface temperatures, cause considerable seedling mortality of ponderosa and lodgepole pine in pumice soils in Oregon. Leaving a light slash cover on the soil surface reduces surface temperature extremes, and at the same time is the only practical means for frost-heaving protection. In areas where natural regeneration is to be featured, seedling protection and fire prevention may not be totally compatible. These results help the manager weigh the benefits and risks involved in slash prescriptions. (808)

501. To evaluate the future importance of oak stands, we need to know the sprouting capacity of northern red oak stumps and the growth of stump sprouts. In southwestern Wisconsin and adjacent Minnesota, Iowa, and Illinois results show that 30–40 red oak clumps per acre might account for one-third or more of a stand's basal area by age 20. The red oak sprouts grow exceptionally fast in height and the conventional sites index curves should not be applied. (813)

502. To make prescriptions on oak stands following clearcutting, we need to know what happens to the advance oak reproduction. Ten years after clearcutting oak stands in Missouri, stump sprouts were taller than either seedlings or seedling sprouts. The taller the advance reproduction before cutting, the faster it grew after cutting. With these guides, preharvest inventory of advance reproduction can be evaluated. (816)

503. Site utilization can be improved by developing systems to encourage natural establishment and growth of yellow-poplar and other high value species. Logging followed by control of leftover wood material is usually adequate for obtaining a satisfactory stand of yellow-poplar. Although there may be some problems with undesirable species, yellow-poplar will usually dominate the better sites. To get quality timber on highly productive Appalachian sites, grapevines need to be eliminated. A study of 40-year-old yellow-poplar stands showed that thinning could increase diameter growth of residual trees by 85 percent. Thus, increased yields and value of yellow-poplar can be expected with periodic thinnings. (815)

504. When should a longleaf pine shelterwood overstory be removed in order to promote optimum survival and growth of established seedlings? In the coastal plain and mountain provinces of Alabama, new stands developed most rapidly if released by age 3, but still responded well when released at age 8. Average seedling size and percent of the stand in height growth can be estimated from seedling age and from years of release from the parent overstory. The final harvest of mature stands can take place in a planned and orderly manner over a period of years after establishment of a new stand. (807)

505. Deficient seed supply is a problem in natural regeneration of longleaf pine. Seven years of testing in south Alabama showed that seedling establishment, survival, and growth could be improved by burning during winter or fall to prepare a seedbed. Mechanical seedbed preparation was helpful after a fire and imperative when no burn was made. Supplemental seed-

ing was needed during 5 of 7 years. Foresters can increase the likelihood of a successful seedcatch with prescribed seedbed treatments and, during marginal seedfall, with supplemental seeding. (810)

506. Alternatives to clearcutting are needed for regenerating upland hardwoods in many instances. Acceptable reproduction developed over a wide range of cutting intensity in Southern Appalachian mixed oak stands. Cutting intensity varied from clearcuts to removal of only one-third of the overstory. Species composition did not appear to be closely related to cutting intensity. Intolerant species such as yellow-poplar became established in the partial cuts as well as the clearcuts. On the other hand, subsequent height growth was strongly affected by cutting intensity with greatest growth on the clearcuts. (814)

507. Willows and cottonwoods are common colonizers on disturbed areas of the taiga and tundra of Alaska, but little is known about the seed biology of these important species. On the basis of timing of seed dispersal, these two genera can be subdivided into two groups—early seeding and late seeding. Early seeding species include both cottonwood and willow, but late seeding species include only willows. Early seeding species are nondormant and germinate completely in 1 to 2 days at temperatures ranging from 5 to 25 °C. Seed of late seeding species germinate slowly and incompletely and require stratification for rapid and complete germination. This information provides insight into the regeneration ecology of these species. (820)

Silvicultural methods

508. Many ponderosa pine sites in the southwest that reverted to bunchgrasses following timber harvest are now difficult to regenerate. It has been found that extracts of the green foliage of Arizona fescue and mountain muhly grasses substantially reduce germination of ponderosa pine seed and also retard elongation rate and total development of their radicales. This begins to clarify the ecological significance of the inhibitor in these grasses and suggests the need for thorough mechanical site preparation of these grass-covered areas. (835)

509. Persistent difficulties with establishing natural regeneration in the high elevation spruce-fir forests of southern Utah have generally defied conventional solutions and prompted a closer evaluation of the ecological succession in these forests. Analyses of age-class distribution of three tree species on two plateaus in southern Utah showed that Engelmann spruce, the primary species, was predominantly all-aged; subalpine fir uneven-aged; and quaking aspen even-aged. This age-class structure suggests that even-aged silviculture may not be entirely compatible with normal stand succession there, and stresses the need for testing an uneven-aged silviculture system in these forests. (828)

510. Forest managers in the central Rocky Mountains face the problem of adjusting timber harvesting practices in old-growth lodgepole pine forests to meet the needs of all key forest uses. New guidelines are now available to aid the forest manager in developing alternatives to clearcutting to meet different stand conditions, windfall risks, and insect and disease, susceptibility conditions. These guidelines provide the manager with cutting options that permit the maintenance of forest cover in recreation areas, travel influence zones, and scenic view areas. (821)

511. The completion of the harvest of old-growth redwood is rapidly approaching and there is national interest in how well this valuable forest type is being regenerated. Research on the Redwood Experimental Forest in California showed that any of three regeneration cutting methods—clearcutting, shelterwood, and selection—produced adequately stocked new stands of trees. Adequate seed coupled with mineral soil seedbed were key factors in getting seedlings established. Sprouting redwood stumps also added up to 60 percent crop trees per acre. Insofar as regeneration is concerned, foresters apparently have considerable latitude in their choice of regeneration cutting methods in this valuable forest type. (823)

512. Western bracken is a major herbaceous species on forest lands in western Oregon and Washington, often forming cover dense enough to preclude establishment of other species. Laboratory and greenhouse studies suggest that water soluble extracts from senescent bracken fronds can prevent or retard the establishment of western thimbleberry, salmonberry, and Douglas-fir seedlings. Therefore, western bracken cover should be reduced prior to establishment of more desirable species such as conifers. (836)

513. There is need for more information about harvesting systems suitable for scenic areas and severe site situations in western hemlock forests. Shelterwood harvesting in western hemlock forests produced abundant regeneration and a good site and overstory survival was good. Shelterwood harvesting is a viable alternative to clearcutting where esthetics are important or where regeneration after clearcutting may be uncertain. (838)

514. To establish black walnut on cleared forest sites, weed control methods need to be determined. In a study in southern Illinois, after 7 years trees were 17–19 feet tall where all vegetation was controlled but only 8–10 feet tall where there was no control or only control of woody competition. Controlling only woody vegetation was no better than no control at all. Walnut can be established on clearcut forest openings if weeds are controlled. (831)

515. Aspen forms the largest and most widely distributed forest type in the Lake States. It is relatively easy to regenerate because it sprouts readily from root suckers. Clearcutting or commercial harvest followed by removing the remaining overstory is recommended. A new Agriculture Handbook devoted to quaking aspen includes a summary of silvical characteristics, pests, yields, reproduction, and management alternatives. (824)

516. Although broadcast burning has been used successfully to prepare nonbrushy clearcut peatlands for black spruce reproduction, unsuitable weather, and hesitancy to use fire suggests that we need another alternative. In a 2-year trial in north central Minnesota, reproduction was rapid and adequate after a full-tree skidding operation was done. For certain conditions, this appears to be an economically sound alternative. (829)

517. Abundant natural reproduction has consistently developed on clearcuts in the Southern Appalachians. However, future species composition is usually uncertain. Ten years after a Southern Appalachian hardwood stand was clearcut on a good site, numbers of stems of desirable species appear adequate to restock the area with yellow-poplar dominating. Some problems are anticipated from grapevines, black locust thickets, and red maple clumps. (833)

518. At times, cleaning costs must be incurred if species composition needs altering to encourage development of a productive forest stand. Rejuvenation of browse or some other multiple use benefit may help justify cleaning if a major part of the cost can be assessed against that benefit. On highly productive Appalachian sites, it appears that elimination of grapevines by cleaning is necessary if quality timber is to be produced. If rotations are to be shortened for some timber species, precommercial thinning may be considered as the first of an orderly sequence of thinnings. (848)

519. Density-related mortality of pulpwood-size trees ranging from 2 to 7 cords per acre was observed in 40-year-old, high-index yellow-poplar sites on the Pisgah National Forest. By using recently developed thinning guides for pure stands of yellow-poplar, it was shown that profitable thinnings could have been made and that diameter growth of selected residual trees would have been increased by 85 percent, thereby stimulating earlier production of saw logs and veneer logs. (849)

520. Difficult regeneration problems have resulted in the continuing replacement of longleaf pine by other southern pines. Fifteen years of research and testing have shown that longleaf pines can be reliably and economically regenerated by the shelterwood system. Because of its low cost in terms of time, money, and energy, and its applicability to small as well as large areas, natural regeneration can be an attractive alternative to clearcutting and planting, particularly for the small landowner. (809)

521. Poor survival of Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) plantings in shrub-covered openings is a serious problem related to many logged-over and burned-over acres in central Idaho. The site preparation needed to reduce competition for soil moisture also exposes the site.

Protection of the site against environmental extremes is important for survival of Douglas-fir on central Idaho sites. Site preparation by scalping increased survival by as much as 42 percent and growth by as much as 30 percent on some habitat types, but not in severe habitats. When relationships between habitat type and site preparation are deciphered, prescriptions can be tailored to fit specific situations thereby reducing costs and significantly increasing survival and growth of seedlings. (830)

Ecological Relationships

522. Aspen occurs on over a half-million acres of the more productive timbergrowing land of the southwestern United States but information on its regeneration, growth, and stand development is very limited. Studies in Arizona showed rapid and complete regeneration by aspen suckers following both fire and clearcutting disturbances. Aspen developed rapidly with the dominants averaging over 10 feet tall after four growing seasons and 24 to 40 feet tall after 22 seasons. Meanwhile, conifer dominants reached only 5 to 12 feet tall during the same period. These results demonstrate alternatives to the land manager showing that aspen stands may be regenerated with clearcut methods or fire and rapid early height development can be expected. (744, 745)

524. Massive volumes of woody residue (up to 250 tons/acre) may remain following harvests of mature Sitka spruce—western hemlock forests, and their treatment is a major managerial question which must consider numerable factions, including effects on regeneration. A comprehensive review was prepared that includes discussions of volume and distribution of residues, decay rates, associated insects and pathogens, nutrient capital, vegetation and tree regeneration effects, and soil and stream channel effects. It provides the coastal forest manager with important background information for managing residues. (817)

525. Because slow-growing longleaf pine seedlings remain vulnerable to fire and cannot be burned for brown-spot control, brown-spot needle blight can become serious in seedling stands retained under a shelterwood overstory. Several regeneration studies in south and central Alabama indicate that the disease is much lighter under a pine overstory than in the open. Light pine overstories were less effective in suppressing the disease than heavier overstories, and hardwood canopies had no effect at all. Natural longleaf regeneration stored under parent overstories of medium densities should not develop a brown-spot problem prior to the final harvest cut. (464)

526. No universal relationships have been discovered between temperature, root aeration, or light and net ion flux to roots of intact plants from culture or soil solutions. In a recent controlled environment study, slash pine seedlings absorbed calcium, magnesium, and nitrate nitrogen from well-aerated culture solutions faster at 28° C than at 22° C or 16° C and faster at 28 than at 22° C. Phosphorus and potassium absorption was higher at 22 than at 16° C, but was not improved by further increasing temperature to 28° C. An oxygen level about 1/2 that of well aerated solutions curtailed uptake of phosphorus, potassium, calcium, and magnesium. This information will enable research scientists to eventually tailor forest fertilization prescriptions to local environments. (786)

ECONOMICS OF FOREST MANAGEMENT

Methods of Financial Evaluation and Planning

527. After wildfire, insects, disease, ice, or wind severely damage a stand of trees, a forester must decide whether to restock the area or to manage the remaining trees. A comparison of rates of return on investments for a severely fire damaged 5-year old slash pine (*Pinus elliottii* Engelm.) plantation in South Carolina indicated that a decision to replace the stand should be postponed for 1 year. Followup to the study proved that the decision was sound; over 70 percent of the trees survived. Forest managers can make sound, cost-benefit-based decisions by applying this procedure. (709)

528. Various studies have looked at the future timber supply to identify potential problems on a regional or national basis. But little or no effort has been made to estimate the cost of bringing forth the anticipated level of supply, nor to relate the identified supply problems to the State level where forestry programs are developed and carried out. In this paper, a static long-run economic model of supply and demand for Georgia's forest is developed. The application of such a model will help identify economic growth goals for the State and evaluate the costs of alternative reforestation methods of achieving these goals. This information is needed by industry, State, federal, and private organizations to help develop policy, set research priorities, and/or suggest action programs designed to get the job done. (1100,1101)

529. The extent to which recreation sites are utilized is becoming a necessary measurement for land management. Instant-count sampling, used in this study to measure recreation consumption, is based on the logical analogy between point sampling and on-site counting methods. One or more instant counts of visitors are made to estimate recreation use in visitor days or visitor hours. The method is particularly suitable for estimating use on small areas or sites which usually cannot be sampled economically using conventional methods. Interval-count sampling is similar but involves some theoretical differences though the basic sampling procedure is much the same. Instant-count sampling proved very efficient in simulated tests and will likely become a commonly used technique to measure recreation use. (1105,1107)

530. The implications of using the allowable cut effect in economic analysis should be recognized. This study shows how use of the allowable cut effect favors growth stimulating practices over inventory protection practices as illustrated by an analysis of the Douglas-fir tussock moth. (1096)

531. Are public forage-seeding investments in thinned ponderosa pine stands economically feasible? Research on this question has led to the development of a tool for estimating the financial return on forage seeded in thinned ponderosa pine stands. This tool is applicable to an array of forage production costs, market-based forage values, and forage production levels. It is useful to public land managers for scheduling forage-seeding investments on both forested and open rangeland. (1104)

532. The small-woodland owner is likely to decide to become a timber producer when he becomes aware of the value of his timber and the income potentials from managing his woodland. This study outlines a method for making stand evaluations that: can be tailored to individual stands and the individual owner's set of circumstances, generate stand values by totaling values of individual trees in a stand, is based on timber quality and changes in timber quality, uses on-the-ground estimates of changes in merchantable height and butt-log grade, can fit in with commonly used timber-cruising procedures, can be adapted readily to many computer programs that have been developed to handle forest inventory data and to make stand projections, focuses treatment results within reasonably short planning periods, and reserves for the owner the choice to do as he sees fit. Such an approach provides timber owners with an improved basis for deciding to become timber producers. (1098)

533. Value is a neglected dimension in timber inventories. This paper spotlights value by presenting a set of tree value conversion standards for hardwood sawtimber, by describing methods for developing and adapting them, by providing a computer program for generating them, and by showing how they can be applied to timber inventories. The availability of value standards and the possibility of altering them to fit local conditions should encourage reporting forestry investigations in terms of value as well as volume. (1099)

534. In order to make rigorous evaluations of timber stands and their development, we need volume and value measures that cover the entire range of merchantable tree diameters. A recent study provides them for pole timber and small sawtimber-sized trees—using Lake States Composite Volume Table Number 6. (1097)

535. Managers on the Flathead Indian Reservation needed guidelines for conducting a precommercial thinning program in lodgepole pine. Economic break-even guidelines were combined with low-precision growth estimates to give a quick and inexpensive means for identifying the most promising precommercial thinning opportunities. The assessment provided managers with preliminary guidelines while awaiting precise information from a detailed response study. (1102)

536. Special user-oriented languages are needed for computer systems with complex and extensive control input, such as physical and economic simulators. MULTIFREE, a package of subroutines to translate such a language, has been successfully applied to both simulation and statistical programs. Users can employ the special language in preparting an input "memo", written in English, which the package compiles and edits into control variables passed to operational program phases. (1103)

Timber Growing Economics

537. Private landowners are increasingly interested in the economics of producing black walnut timber. This study analyzed investment models for black walnut and demonstrated importance of combining economic guidelines with owners' objectives to evaluate black walnut investment opportunities. Results are useful to large numbers of private woodland owners interested in walnut production. (1111)

538. Most models of forest dynamics are in the form of non-simultaneous regression equations. Such models are not capable of capturing the essence of the interactions taking place between components of the stand. A study presents, through diagrams and equations, an approach to modeling forest dynamics which uses simultaneous differential equations. The information presented represents a significant departure from existing growth modeling methodology and holds considerable promise for further development. (1120)

539. Long-range projections of future timber supplies are necessary for planning wise use and management of red pine plantations in the Lake States. Projections of red pine timber supplies for the Chippewa National Forest in northern Minnesota using Timber RAM indicate that red pine sawtimber cut may be increased eightfold in the next 50 years for the Forest. Red pine sawtimber supplies will increase in similar fashion throughout the Lake States as plantations established since the 1930's mature, with potential harvest cut increasing from 30 MMbfm to 500 MMbfm for the region. Although this increase is small from a national standpoint, it is a significant increase regionally. (1121)

540. Hundreds of thousands of acres of southern pine reach thinning age each year, but labor intensive methods make thinning economically infeasible. Data on the Timberline TH-100 Thinner-Harvester, a Caterpillar 950 Tree Harvester, and a Soderhamn Go-Go Harvester suggest alternative means of making early thinnings pay. Use of these thinning systems makes it possible for forest industry to salvage otherwise unmerchantable thinnings and up growth of residual stands to expand present and future wood supplies. (1109,1115)

541. Unionization in southern forest industry seems to be increasing. This analysis of historical and legal backgrounds of labor organization gives a basis for understanding current and prospective developments. The knowledge provided can help

management adapt to upcoming changes in labor relations. (1116)

542. Foresters do not generally have a satisfactory knowledge of the existing literature on labor relations. The selected bibliography is designed to fill this void. Public and private foresters can rely on the suggested readings to increase their understanding of forest labor relations. (1117)

543. Geneticists need economic criteria for setting goals on characteristics to breed into a species. Wide ranging simulations found that genetically improved stock providing a 10-percent increase in growth could double net revenues. Genetic improvement that assures adequate growth without fertilization would make marginal sites profitable. If achieved, these genetic gains would greatly increase acreage devoted to sycamore production and output by land managers. (1113,1114)

544. Program managers are often asked to justify expenditures for genetics research. A new approach to projecting economic gains from genetically selected forest trees estimated increases in revenues from loblolly pine that ranged up to 150 percent or $20 per acre annually. The method promises to become a valuable tool for foresters for evaluating genetic crosses, and for assessing impacts of genetically improved stock on managment programs. (1124)

545. Institutional arrangements are needed in the South to achieve improved management on small tracts. Analysis of the tree farm family movement found it to be largely successful. Details of the programs vary. The results can help forest industry to establish new programs and expand existing ones and thereby increase regional timber supplies. (1122)

546. Small tract owners are not easily attracted to forest investments. By focusing on a single ideal practice such as timber stand improvement with small capital requirements, high payout potential, and a short investment period, owners can be induced to invest. Given a first rewarding experience, they will progressively undertake more intensive management. (1110)

547. Municipal programs to suppress Dutch elm disease have had highly variable results. Performance as measured by tree mortality was unrelated to control strategies. Costs for control programs were 37 to 76 percent less than costs without control programs in the 15-year time-span of the study. Only those municipalities that conducted a high-performance program could be expected to retain 75 percent of their elms for more than 20 to 25 years. Communities that experienced the fewest elm losses had a well founded program, applied it conscientiously, and sustained their efforts over the years. This information will be useful as guide to municipal planners in developing effective disease control programs. (1112)

548. State foresters and consulting foresters have expressed a need for an approach to include economic criteria in timber marking. The approach developed by Trimble, Mendel, and Kennell is prescribed and adapted to the TSI problem. Also, the economic requirements for precommercial investments in timber management are developed. Timber managers using these techniques in the field will produce economically sound results. (1126)

549. Resource analysts, planners, and wood industry representatives have long needed a practical method of estimating current removals of timber for local areas of the Northeast. Stepwise multiple regression analysis was used to develop equations for estimating subregional removals of softwood, hardwood and all timber. The models are easy to use and appear to work quite well for areas of a million acres or more. They provide valuable working tools for all agents concerned with the use and development of the Region's forest resources. (1118)

550. Decisions that Pennsylvania's private woodland owners make today about the use and management of their woodlands will have major impact on the future availability of forest products and services. Yet little is known about forest-related behavior of this important group of decision-makers. A study conducted to help fill this knowledge gap provided a wealth of meaningful information for assessing the role of private woodland owners as suppliers of forest products and a basis for significant policy related inferences. For example:

> Most owners are over 50 years of age and are not likely to be interested in actions that yield payoffs in the far distant future.
>
> Large acreage owners are apparently the best targets for programs aimed at improving woodland productivity since they are more willing and better able to satisfy society's requirements for forest products. (1119)

551. Economic guidelines are needed to manage lodgepole pine. Lodgepole pine stumpage values are relatively low, logging costs are higher than average, and few investments can be justified in dollars and cents. The shortest rotations producing market-sized timber generate the highest discounted values; neither schedules of commercial thinnings, low discount rates, nor the substitution of cubic foot for board foot measurement makes much difference. Noneconomic rationales or radically increased stumpage values are necessary before lodgepole pine will become of more than local importance. (1125)

552. As growth in timber demands continues to exceed growth in supplies, both public agencies and forest industries are renewing interest in small and medium-sized private ownerships as sources of additional timber. Higher production costs and other economic factors put small tracts at a disadvantage. This study attempts to measure the effects of tract size on financial returns per acre. Results indicate the major influence of tract size and suggest the large potential advantages of multi-tract or multi-ownership management. (1123)

553. Management of forests for multiple objectives presents unique resource allocation problems to today's forest managers. Goal programming (a variant of linear programming) was used to allocate 10,641 acres to eight alternative uses in order to meet, in so far as possible, a set of prescribed goals. The goal programming model was shown to be of considerable potential as an analytical framework for solving multiple-use forest management problems. (1138)

Multiple-use Economics

554. The systems approach to studying forests has given explicit recognition to the interaction of system elements. But foresters have not had a conceptual framework to work from in attacking this problem of understanding and controlling forest interactions. A generalized framework had been suggested for ecologists several years ago by Edward Haskell but it has been almost totally ignored. We analyzed this framework for its usefulness, made minor corrections, completed it and demonstrated

its use. We anticipate that this mathematical coordinate system will become a standard tool for analyzing and reporting interactions in ecology and forestry. (1128,1131)

555. Water is often the only product from forested municipal watersheds. The once formidable barriers to multiple use of watershed forests is indefensible today. Properly located and constructed roads cause little damage from sedimentation. Dangers to health from public use are exaggerated. Watershed managers can achieve both multiple use and purity of drinking water. (1127)

556. Average costs for providing different forms of outdoor recreation are critical considerations for land-use planners. Cost-per-unit of recreation use was developed for almost all kinds of recreation sites and areas found on National Forests in the South. This work is unique in that it includes a measure of the losses in timber value, or opportunity costs, that occur from managing the land for recreation. Results indicate that the opportunity costs are generally insignificant for developed sites but become highly significant on dispersed sites such as wilderness areas. Costs developed in this study will be critical inputs for budgeting, capital improvement planning, and for pricing or setting a user fee for recreation. (1141)

557. Thinned timber stands can produce more forage for cattle in addition to accelerated timber growth when economic guidelines are used to coordinate timber and range management planning. Forage production is estimated for interior Northwest National Forests with grass seeded in timber stands that are presently scheduled for thinning in the next 15 years. (1147)

558. Future rural development in the Great Plains will result from increased activity in recreation and mineral extraction. Such development must be based on new concepts, regulations, and laws concerning land ownership, reclamation, and water use. The social and economic considerations must be carefully evaluated and a statutory basis established to guide land use planning. This paper sheds light on these rural development problems. (1129)

559. Vacation home developments grow and change in ways similar to urban subdivisions. In the early stages, they have relatively high benefit-cost ratios in respect to their requirements for government services. These ratios decline over time, and without careful planning, they can be reversed. County officials and land developers must provide early guidance to insure that these developments are not detrimental to county revenue-cost relationships in the long run. A new paper highlights problems and factors to be considered by developers and government officials in providing this guidance. (1130)

560. A sampling of the pressures for various multiple-use activities shows the complex situations created by multiple-use management, the concerns that municipal watershed managers should have, and the importance of preplanning, with particular reference to facilities shared by all the uses eventually selected as the watershed's multiple-use package. A five-step approach is described and illustrated by example for selecting multiple-use activities to feature and for adjusting a package of activities to match the funds available for shared facilities. Use of this technique will place municipal watershed land use decisions on an objective basis. (1143)

561. Very little information about Ohio's forest trails and trail users is available. Types of trails (their purpose and location) and kinds of trail users (who they are and why they use trails) are discussed. There is important information here for trail users, planners, builders and managers attempting to optimize trail use enjoyment. (1132)

562. Private woodland owners are not motivated or able to make the investments necessary to provide adequate supplies of timber or wildlife. Incentives offer a legitimate and promising means for getting them to take action. A recent paper discusses the important role of private woodland owners as suppliers of timber and wildlife. It also presents a practical method for deriving fair incentive payments for timber and wildlife practices and demonstrates its application. (1140)

563. The economic values of all forest resources at local, regional, and national levels are needed in land use decisions so trade-offs can be quantified. A recent study found that about one-fourth of each tourist dollar accrues to Montanans as income; the proportion is highest for motel- and restaurant-dependent tourists and progressively less for hunters, fishermen, and campers. It is unlikely that growth in tourism could offset income losses resulting from even moderate declines in timber harvesting. Further, there are many differences in the nature of the jobs and in secondary economic consequences of jobs in the two industries. Land uses favoring either industry have a variety of subtle consequences. (1133,1134)

564. To guide research, a better understanding of data for land use planning is required. Socioeconomic data are used in land use planning in Idaho primarily in a descriptive, rather than analytical, manner; the necessary analytical skills are rare among planners. Planners feel that recreation data, and especially that concerning economic values of nonmarket commodities, are the most important and least available. While most planning now encompasses a time horizon of 15 years or less, projections of socioeconomic activities are needed for up to 50 years. This points up the need for more effort to provide data in a form that will be used. (1135)

565. Land use decisions of public land managers are subject to public scrutiny. Demonstrating technical credibility, structuring decision processes in ways that minimize conflicts among special-interest groups, and favoring alternatives that permit future changes in direction reduce the chance that such decisions will be reversed. (1139)

566. Consistency across groups of judges in evaluating esthetic attractiveness is necessary if such judgments are to lead to management guidelines. Four groups with differing backgrounds (undergraduate psychology students from the Universities of Michigan and Montana, Montana elementary school teachers, and Forest Service landscape architects and researchers) rated slides of forest conditionsin a consistent manner. Uncut old growth and young regrowth were preferred to recently cut areas. The elementary school teachers provided the most extreme like-dislike ratings; the professional foresters provided the least extreme ratings. These findings generally support results found elsewhere in the country. (1142)

567. Sociological and economic analyses of investments in natural resources have traditionally been conducted separately. A procedure for integrating economic cost-benefit analyses with standard sociological analyses is outlined in a recent report. This procedure may aid the decision-maker in selecting those alternatives that combine long-term policy considerations with short run economic efficiency objectives. (1108)

568. With mounting pressures and conflicts in recent years over land use, the Forest Service has found itself in controversy over multiple-use of forest lands. Development of methods of economic analysis for multiple-use alternatives has proved more difficult than severest skeptics imagined. A recent study summarizes economic approaches that appear to have promise, planning methods that have been developed, and major areas in which future work must be concentrated. (1136)

Impacts on Forest Industry and Regional Economics

569. Solution of the wood industry's pollution problems requires that they be understood in economic terms. This study examines basic economic concepts and facts needed to understand the problems, and discusses impacts of environmental and pollution control policies on the industry. Long-run viability of the wood industry does not appear to be threatened by pollution control costs. (1106)

570. What can be done when demand for pine products increases drastically? Analysis shows that the major bottleneck would be a shortage of management talent on which to expand the logging industry. Product mix changes within plants would ameliorate the problem somewhat. Price rises would shift some of the demand to western species. Forest managers need to expand timber supplies and allocate cutting on a different basis in good markets than in poor ones. (1145)

571. Reports from major timber-producing regions of the world stress woods labor problems. Analysis shows that the problem in the South is largely in pulpwood logging. To equalize employment opportunities, the prime pulpwood contractor of the future will be a multiproduct logger. An adequate supply of prime loggers with the requisite managerial ability will reduce the industry's concern for supplies of southern woods labor. The result will be greater markets for southern timber products and for stumpage combined with higher quality employment in the woods. (1146)

572. Fusiform rust is the most damaging disease of pine trees in the South, but little is known about the financial impact of the disease. Incidence data from forest surveys applied to the South indicate an annual loss to fusiform rust of $28 million in 1972. The loss offers a measure of the possible savings from efforts by protection agencies and tree breeders. (1148,1149)

573. A thorough understanding of the wood products industry is required to conduct an effective timber harvesting program. This study found that new capital expenditures in Montana have been high, but value added per employee is relatively low. Earnings exceed those of other State industries and the United States forest products industry, but such employment is extremely hazardous. The work force is younger, has less formal education and is less skilled than in other industries. Timber harvesting supports a substantial workforce that is important to Montana's economy. (1147)

574. Assessing changes in timber harvest levels requires forecasts of consequences in dependent communities. Data are provided for each Idaho county and for broad State planning regions that define the degree of area specialization in the forest products industry, the local job dependency on this industry relative to other industries, and the local impacts of a changed level of employment in the forest products industry. Estimates of economic consequences of timber harvest changes in the State are possible from this data. (1150,1151)

575. Forest Service unit planners do not have efficient analytic tools to complete required environmental impact assessment and to analyze the consequences of alternatives in each unit plan on the local economy. An export base model, with the required data file, analysis procedure and computer program, have been developed for local economic base analysis that permits unit planners in the Southeast to predict the economic effects of alternative proposals. Computer terminal and program are used to perform the analysis in a conversational-interactive mode. These methods enable land unit planners to better assess local economic impacts of unit plan alternatives in the Southeast. (1144)

576. To better determine future wood supplies in the U.S., the trends, needs, and potential impact of intensive culture of public and private forests need to be assessed. A nationwide survey indicates that although investments in cultural practices will increase greatly in the next decade, annual wood harvests from industrial lands are expected to increase only 10–15 percent. Similar investments on National Forest, other public, and small private ownerships will be needed to effect any major increase in total national wood harvest. This information helps managers determine national needs and priorities for intensive forest culture. (1152)

577. Intensive management of short-rotation crops will be highly expensive and must be evaluated carefully. An analysis was made that lists factors affecting production of forest crops; provides estimated costs per acre of land, land preparation, planting, management, harvesting, hauling, and processing; and discusses their management implications. Data presented are useful for economic assessments of short-rotation systems. (1083)

WEATHER MODIFICATION AND WEATHER EFFECTS

578. Accurate knowledge of the surface temperature, relative humidity, and wind velocity is necessary for estimating fire danger and fire spread in forested mountainous areas. A meteorological research telemetering network accurately measures temperature, relative humidity, windspeed and direction, and net radiation. These data are being used to: (1) Validate and improve mathematical models for diagnosing and predicting these weather elements in mountainous terrain; (2) determine optimum number and placement of meteorological observing stations for an operational network in southern California; and (3) develop adequate interpolation techniques for the operational network. (734,735)

579. Wind variations in a forest clearing can cause snow to accumulate and trees to blow down. This study investigated the nature of wind distribution in a clearing in an even-aged, somewhat idealized lodgepole pine canopy. Eddies were found to shed periodically from the upwind surface of the clearing. This phenomenon will complicate efforts to model wind effects of forest clearings.. (712)

580. The wind field in mountains is the single most difficult factor encountered in evaluating forest fire spread and pollutant dispersion. A simple, one-layer model of atmospheric boundary

layer flow was developed for use in complex terrain. The model requires much less data than traditional approaches; therefore, it can be used as an estimator of wind patterns in areas where dense observational networks are not economically feasible. The model is intended for use primarily in fire behavior prediction but also has application in the evaluation of pollution transport patterns. (732)

581. Modeling the behavior of western mountain watersheds requires a detailed snow melting simulation. Snow melts because of an input of energy to the surface; therefore, a model is proposed for the solar albedo of natural snow cover. The model suggests that for grain sizes larger than 1.5 mm, density is the primary factor governing albedo. This information is necessary to determine the melting characteristics of a snow pack. (531)

IMPROVING UTILIZATION AND EXTENDING WOOD SUPPLIES

INTENSIVE CULTURE METHODS

Site Evaluation and Soil Improvement

582. Frost heaving is a leading cause of tree seedling mortality in many parts of the world. Studies in Arizona show that the rate and amount of frost heaving increases with increasing bulk density, that indexes utilizing bulk density and sand content of the soils are useful predictors of frost heaving susceptibility of forest soils, and that measures which lower bulk density, such as plowing or disking, reduce heaving. These results help the forest manager detect where tree regeneration may be adversely affected by frost heaving and offer some possible measures for reducing this damage. (812)

583. Thinning dense forest stands generally stimulates growth, but the relationship of nutrient levels to stocking density after thinning has not been established. Eight years after thinning of a 43-year-old pine stand in Arizona, the total forest floor litter component weights and total nutrients were found to be directly proportional to the basal area stocking level. However, the tree foliar nutrient concentrations were not affected. The longest and heaviest needle fascicles were found on the area with the least basal area stocking. This basic information is essential for more fully evaluating stand density effects in ponderosa pine forests. (761)

584. Clays play an important role in forest soil nutrient and water status, affecting tree regeneration establishment and subsequent growth, but some of the basic soils information needed for assisting silvicultural and management prescriptions is inadequate. An analysis has recently been completed of the types and amounts of clay minerals found in many Montana soils. Mica contents are generally high in the forested soils of western Montana, and many of the soils there have a thin mantle of volcanic ash containing amorphous clays. These results provide basic information for evaluating soil-dependent forest management activities. (759)

585. Accurately evaluating forest site quality has been a major problem since the beginning of forestry in America, and a large volume of sometimes confusing and contradictory literature has accumulated for most of our important tree species. This comprehensive review traces the history, summarizes the present status, and suggests site quality goals for the future. The coordination and integration of all site evaluation methods is emphasized, as well as integration with yield prediction and methods for landscape classification and mapping. (756)

586. The growth rate of planted slash pines varies considerably on sandhill sites. Examination of sandhill soils in 91 plantations established in west Florida called attention to the tremendous variation in physical characteristics. Layers of fine-textured soil found at various depths in these excessively drained soils are known to retain moisture longer than sand and to retard percolation of water through the soil profile. In the sandhills, slash pine grows best where fine textured soil is not more than 12 feet below the surface. Site index decreased 1 foot for every 9 inches of depth to the fine textured soil. Site preparation does little to alter the inherent productivity of sandhill sites. This information will help land managers to identify those sites within the sandhills suited to slash pine. (757)

587. Soil nitrogen status might be improved if the factors that control nitrogen fixation in forest soils were known and could be manipulated. In the South Carolina Coastal Plain, nonsymbiotic nitrogen fixation was less than 1 Kg/ha/yr in upland mineral soils but over 10 Kg/ha/yr in swamp soils. To get high nitrogen fixation in upland soils, an addition of phosphorus and an energy source were required. In loblolly pine stands, an available energy supply of leaf litter is limiting and a significant increase in soil nitrogen by nonsymbiotic fixation does not seem feasible at this time. (758)

Artificial Regeneration

588. Artificial seeding of ponderosa pine after timber harvesting in the Sierra Nevada of California has been unreliable for establishing new stands. A seeding study there shows that 400 seedlings per acre can be established by 1) preparing 100 percent of the site by piling and burning slash and residual vegetation; 2) treating seed with endrin-arasan-aluminum dust pest repellent treatment, or equivalent; and 3) seeding at least 10,000 viable seed per acre. This prescription for seeding ponderosa pine in the westside Sierra Nevada forests is a reliable management option which is cheaper than planting. (897)

589. Planting is the most reliable method of regenerating ponderosa pine in the southwest but planting is expensive. Tests in Arizona showed that spot seeding of pine produced consistently more seedlings than broadcast seeding, that frost heaving and drought accounted for most seedling mortality, and that direct seeding results were extremely variable, even on the most favorable sites. Because there is no net cost advantage of direct seeding over planting and the success rate is less predictable than with planting, direct seeding should be reserved as a flexible tool to promptly regenerate only the best sites when planting stock is unavailable. (900)

590. The traditional fall season for prescribed burning of logging slash in larch forests of the northern Rockies has been too short, and we haven't known how effectively we could prepare a seedbed by burning during other parts of the season. Studies in northwest Montana show that to accomplish near-complete duff reduction, north aspects had to be burned during the summer before the onset of heavy autumn rains, but that the other aspects had a much longer time period in which to burn effectively. Spring burns did not significantly decrease the duff layer on any aspect. The burning conditions required to prepare an adequate seedbed are now better defined, and more precise burning prescriptions can now be made for larch forests. (819)

591. Reforestation efforts are rapidly becoming more dependent on containerized tree seedlings, but supporting information

is fragmented and incomplete. Several recent reports broadly summarize the status of container-grown seedling production and use, present guides for starting greenhouse container operations, describe new devices and techniques, compare containerized and bare root systems, and describe problems yet to be resolved. These reports provide reforestation specialists with information needed for developing and evaluating containerized tree seedling programs. (902,905,906,907,909)

592. Hardwood nurserymen need a way to prevent seedlings from becoming too large to handle effectively. Two growth retardants were tested for nursery use to control size of five hardwood species. Alar slowed growth of lilac and cotoneaster. Slo Gro stopped growth of Siberian elm and slowed growth of honeysuckle and cotoneaster. Chemicals were less effective than undercutting on green ash. With proper use of growth retardants on some species, nurserymen can carry over and sell stock that would otherwise have to be destroyed. (908)

593. Expanded planting programs on National Forests have forced nurserymen in some cases to adopt high density sowing rates of forest trees in nursery beds. A bed density study at Wind River and Humboldt nurseries in the Pacific Northwest showed that seedling stem diameter and field height growth decreased as bed density increased from 10 to 70 trees per square foot. Therefore, increased nursery production probably should be obtained by expanding nursery bed space rather than by growing seedlings at higher densities. (885)

594. Adverse environmental conditions and/or poor choice of seed source can hinder successful plantation establishment. In the case of basswood in Indiana and Illinois, site proved to be more important than seed source. Clearcut openings were a much better environment for basswood development than were old fields. Intensive care is needed to insure success for basswood plantation establishment. (822)

595. Eastern white pine is widely planted in areas outside its natural range and we need to determine the best adapted sources of seed. Test plantations in Illinois, Indiana, and Kentucky all showed similar results with the best sources 70–80 percent superior to the species average. A large seed collection zone comprising most of the southern part of the natural range is recommended for white pine seed collection for use in the Ohio Valley plantings. (887)

596. The cost of converting Sandhill land from scrub hardwoods to pine can be reduced substantially if seeds instead of seedlings can be used to establish such plantations. A recent study showed that longleaf and Choctawhatchee sand pine can be successfully established from seed if the sites are thoroughly prepared, and if the seeds are covered with a thin layer of soil when sown. Well-stocked stands developed where cultipackers drawn by farm tractors had been used to cover the seeds. Machine seeding either longleaf or Choctawhatchee sand pine in rows affords managers of Sandhill land in the Southeast an opportunity to conserve about half of their seeds, to space seeds accurately, and to complete distribution covering of the seeds in a single operation. (894)

597. Warm, wet summers offer an opportunity to extend the season for converting millions of acres of droughty, scrub hardwood-dominated Sandhills land in the Southeast to pine by direct seeding. Results of planting longleaf, slash, Ocala sand, and Choctawhatchee sand pine seeds at biweekly intervals for two consecutive years show that direct seeding during the summer is impractical. However, seedling establishment was best when daily high temperatures averaged no more than 71°F (22°C) and daily lows no less than 38°F (3°C) during the 10 weeks after seeding. Where local guidelines are lacking, these findings can be used with published climatological data to determine the best time to seed the four pines. (884)

598. Sand pine seedlings produced within their natural range of Florida and coastal Alabama seldom remain dormant throughout the entire winter. Consequently, storage, handling, and transplanting of these seedlings is more restrictive than for other southern pines that usually remain dormant. It has been found that transplanting success is best if sand pine seedlings are lifted in January or early February in quantities than can be planted within 1 week after lifting. Bales or bags of seedlings should be stored unstacked under shade. Land managers are advised to order the Choctawhatchee variety of sand pine in preference to the Ocala variety and to follow recommended storage and handling procedures. (882)

599. The cost of reforestation in the Sandhills of the Southeast would be substantially reduced if sand pine could be planted with little, if any, site preparation. Through age 5, Choctawhatchee sand pine (CSP) planted on prepared sites attained an average height of 10.6 feet with 95 percent survival. Under these same conditions, Ocala sand pine (OSP) reached an average height of 12.2 feet with 90 percent survival. When planted in the woods, CSP attained an average height of 5.4 feet with 84 percent survival through age 5. Under the same conditions and in the same period of time, OSP attained an average height of 7.6 feet with 74 percent survival. Sand pines planted on prepared sites seem destined to produce more wood sooner than others planted in the woods. (883)

600. Economic success of hardwood planting programs depends on the ability of seedlings to survive and grow rapidly. Sweetgum seedlings with root-collar diameters greater than 1/4 inch survived and grew better than small seedlings. Morphological grades of sweetgum seedlings are a good measure of early growth potential. (878)

601. Increased wood demands have focused attention on the production potential of hardwoods. Intensive cultural practices have now been developed for the management of commercial hardwood plantations in the South. Careful choice of planting areas, thorough site preparation, graded planting stock, and intensive cultural treatments are essential to assure plantation establishment. Growth of plantations grown under intensive culture averages between 3 and 4 cords per acre per year. Practical methods are now available for growing hardwoods under several management systems and for different product goals. (879)

602. Artificial regeneration with desirable oak species may be one way to improve the culled, understocked hardwood stands of Tennessee's Cumberland Plateau. It has been found, however, that white, northern red, and black oaks can be established by direct seeding only if acorns are protected and competing vegetation is controlled. Survival after 4 to 7 years averaged 42 percent in coves and 70 percent on upland plots. Height growth was slow. This information provides regeneration specialists good insight about the requirements of successful direct seeding. (895)

603. Little is known of the effect fertilizers have on longleaf pine seed production and quality. Eleven years of data show that complete fertilization increases cone production and seed size, but does not influence the number of seeds per cone, proportion of empty or wormy seed, cone size, initial viability, or keeping

quality. Correlations between adjacent years for cones per tree, sound seeds per cone, percent empties, seed weight, and cone size show these are characteristics of individual trees, but storage quality of seed is not. Germinability is not associated with number of seeds per cone, cone size, or seed size. These data will be useful in management of longleaf seed orchards and to scientists working with pine seeds. (891)

604. Finding a practical, effective container is essential for planting tubelings in the South. Survival and growth of 6-week-old containerized loblolly seedlings grown in soilless wood-fiber blocks were higher than in soil-filled Kraft-paper tubes when outplanted at the same time. Survival of longleaf seedlings in blocks was lower than in tubes, but growth was markedly better. Although growth from a late August planting was not satisfactory with either species, results show that soilless blocks may provide an improved means for regenerating southern pines in certain situations. Results will be useful to foresters and nurserymen evaluating containerization materials for southern use. (875)

605. The normal cone collection period for southern pines is only about 3 weeks. By storing cones for 5 weeks at air temperatures, collections of slash, loblolly, and longleaf can be started several weeks earlier than usual without impairing seed yields or viability. Yields increased with increasing lengths of storage from 1 to 5 weeks with all species. Germination of slash pine was increased by long storage for all dates of collection, had no effect on longleaf and loblolly, except it decreased viability from the earliest longleaf collection. The annual harvest of southern pine seed can be almost doubled in many situations by applying this information. (892)

606. Use of an aerial multiple-row seeder will overcome most of the objections of broadcast direct seeding, and still retain its advantages. A test was installed to determine if the downward velocity given the seed to reduce deviation within rows seriously affects viability or causes excessive penetration into mechanically prepared soil. Loblolly pine seeds, given a clay coating were sown on different soil-type and site-preparation treatments. Soil penetration was not a problem and viability was not reduced unless seeds hit some hard object such as a rock or stump. Results should benefit silviculturists, artificial regeneration specialists, and agricultural engineers interested in further development and utilization of the aerial row seeder. (877)

607. Information on managing southern pines is available, but no single authoritative source exists. Proceedings of a recent symposium assembles 53 papers on virtually every aspect of southern pine management. They cover such diverse topics as regeneration techniques, precommercial thinning, insect and disease control, growth and yield, landscaping, range and wildlife opportunities, water resources, tree improvement and genetics, and Federal income tax guidelines. Managers of southern woodlands will find the proceedings to be a valuable source of useful information. (853,890,923,924,928,952)

608. Increased production of sycamore seedlings for planting in the South is hampered by the problem of low percentages of filled seeds in many lots. However, tests over a 3-year period have demonstrated how empty seeds can be mechanically separated from filled seeds. Small samples can be upgraded to 90 to 100 percent filled seeds with laboratory blowers. Medium- to large-sized lots of 20 to 30 percent filled seeds can be upgraded to 50 to 68 percent with a gravity separator. Southern nurserymen who grow sycamore can reduce cold storage requirements by as much as 75 percent and nursery costs by as much as 25 percent by the recommended seed handling procedures. (881)

609. Special tests of seed lot vigor are needed for complete evaluation of seeds. Tests with cherrybark oak acorns of variable quality show that germination rate is significantly correlated with tetrazolium staining, growth, and exhaustion but not with oxygen uptake or carbohydrate leakage. None of the tests correlated significantly with germination percentage. Seed scientists now know which tests have promise for future work and which ones can be eliminated from consideration. (880)

610. Interpreting radiographs is difficult because of superimposed images and because sectioning and photographing are destructive and time consuming. Tomograms provide clearly distinguished internal structures of predetermined planes at 1 mm. increments in large tree seeds. The major advantage over radiographs is that actual measurements may be determined within 1 mm. A specialized instrument is required for this technique, but film and developing are standard as for radiographs. This technique is significant to anatomic, taxonomic, and pathologic investigations, as it leaves the seed undisturbed and viable for germination. (911)

611. Control and regulation of germination is stymied in some species by a lack of understanding of the underlying causes of seed dormancy. During stratification and germination, carbohydrate and lipid contents in water oak embryos diminish, and both substances shifted from cotyledons to embryo axis. Carbohydrates, lipids, and proteins move to the root apex as germination is completed, but proteins, unlike carbohydrates, originate near the shoot apex and not in the cotyledons. This information contributes greatly to the research effort, which seeks to learn the cause of tree seed dormancy and how we can control it. (912)

612. Many clay soils in the lower Mississippi River Valley are subject to annual overflow. Tree reproduction on such sites is slow growing and tends to undesirable species. Ten- and 14-inch cuttings of 1-year-old green ash planted horizontally 1 to 3 inches deep on problem sites in northern Mississippi sprouted and grew well, as did vertical cuttings and seedlings of the same species. The technique provides an alternative for reproducing a highly desirable species on difficult sites using mechanized equipment. (888)

613. Because of limited equipment, it is sometimes necessary to start picking Douglas-fir cones before the ideal collection date. It is important to know whether or not early collection causes any problems. A case history of 309 trees in Oregon showed that seed collected more than 3 weeks before seed fall begins was much more difficult to extract, was lighter, germinated less than half as well as normal seed, and produced weaker seedlings. With this knowledge, forest managers are forewarned not to collect seed before it is fully ripe unless they are willing to sustain certain losses. (898)

614. In the humid, lowland tropics of Puerto Rico, tree seedlings must grow rapidly if they are to outgrow weeds and be successful. Three species of Eucalyptus, planted on different sites, survived and grew acceptably and look promising for reforestation in Puerto Rico. (913)

615. Container-grown forest tree seedlings are being planted in increasing numbers because of better survival and faster initial growth rate, but containers can produce malformed root systems that cause windthrow, retarded growth, or even death

many years later. A 2-year evaluation of *Pinus ponderosa* seedlings grown in different containers showed that seedlings grown in containers with no walls had no more spiralling than seedlings that had never been in a container. Seedlings grown in containers with vertical grooves have less root spiralling than ones grown in smooth-walled containers. A method has thus been found to insure that the early benefits of container-stock are not negated later in the life of the tree. (904)

616. Establishing Douglas-fir seedlings on hot, south-facing cutblocks is often a difficult task. Deep planting and stem shading—techniques that often improve growth and survival of other species on droughty south slope sites—failed to benefit Douglas-fir planted in northwestern California. Although survival rates were the same, February plantations on this 2000 foot elevation site averaged 20 percent greater 10-year height growth than did the March plantations. These results should help improve planting results on the low elevation sites of northwest California. (903)

617. Nursery stock performs best if lifting and transplanting are done when the stock is dormant. A method of readily determining dormancy is now available. It employs a portable square wave generator and oscilloscope. The physiological state of the plant can be determined from an electrical response which can be evaluated by the shape of the transmitted wave form displayed on the oscilloscope screen. This tool should prove valuable in determining the proper time for lifting nursery stock. (886)

Stand Improvement

618. Effective and inexpensive methods are needed to thin pole-size hardwoods and control undesirable hardwoods in the Ozark Mountains. Tordon 101 and 2,4-D were injected into a large number of hardwood species in the dormant and growing seasons. Tordon was generally more effective than 2,4-D and tended to cause crown kill sooner after dormant season application. Both chemicals were effective when applied during the growing season on all species tested except red maple, ash, and dogwood. These results will help land managers determine effective methods of hardwood vegetation control to suit their objectives. (855)

619. Saligna eucalyptus is a high yielding species in Hawaii plantations but little is known about culturing it in stands. Studies show that thinning these plantations (10 × 10 foot initial spacing) at age 6 to three different basal area levels resulted in no significant improvement in growth over that of the unthinned plantations. These preliminary results indicate thinning should probably be delayed until age 15 when basal are approaches 200 sq. ft. per acre. These results suggest that management costs can be held down without jeopardizing growth of young eucalyptus. (873)

620. On high rainfall areas in Hawaii, planted tree seedlings must grow rapidly to compete successfully with other vegetation. Fertilizing Australian toon and Queensland-maple seedlings with slow release Osmocote at the time of planting at least doubled the height growth over that of unfertilized counterparts. As a result, less than one-half as many of the fertilized seedlings require maintenance to prevent their being overtopped by competing vegetation as do unfertilized trees. These results indicate that savings in maintenance costs are possible by fertilizing seedlings with Osmocote at the time of planting. (871)

621. Precommercial thinning in coastal Douglas-fir forests is a generally accepted cultural practice but when, how, and where to thin needs to be better defined. Improved guidelines for precommercial thinning in Douglas-fir stands have been developed. Precommercial thinning prescriptions depend strong on size of trees desired at the first commercial cut; the larger this size (1) the fewer trees should be left after thinning, (2) the greater is the tree size at which thinning is practical, and (3) the greater is the gain in usable yields. The new guidelines will help determine feasibility of precommercial thinning practices in young Douglas-fir forests. (865)

622. Thinning and fertilization are both recognized as methods of increasing usable wood production, but fertilization responses are largely unknown for lodgepole pine. Fertilization with N, P, and S produced large increases in lodgepole pine wood volume and understory grass production the first 4 years after application. Indications are that radial wood growth will continue longer than 4 years. These and subsequent results will help determine the feasibility of fertilization in lodgepole pine forests. (843)

623. As forest management intensifies in the mixed conifer forests of eastern Oregon, information is needed on growth and yield of managed stands so stocking level regimes can be formulated. Results from a western larch thinning study showed that 55-year-old previously unmanaged larch responded moderately in diameter growth as stand density increased, but height growth was not affected. Thinning from below produced more favorable results than thinning from above. This information corroborates other findings that encourage early stocking control of this important intolerant species and discourage thinning from below. (867)

624. Herbicides are useful for site preparation and release on forest lands in the Pacific Northwest but precise prescriptions are needed for them to be effective. A working manual now available summarizes 20 years of research and experience on herbicide use and treatment prescription. Included are five basic considerations: (1) herbicide selection, (2) amount of herbicide, (3) herbicide carriers, (4) spray volume, and (5) seasons for application of herbicides. This information will enable the forester to better select herbicidal treatments keyed to silvicultural objectives attuned to variations in plant communities and environmental conditions. (856)

625. Overall nutrient cycling and fertilizer effects in Douglas-fir and western hemlock forests of the Pacific Northwest are largely unknown. Factors beginning to emerge include findings that (1) conventional harvesting can remove substantial N from the ecosystem, (2) hemlock growth response to fertilization appeared higher in vigorous stands and more consistent in the Cascades than along the coast, (3) foliarly applied nitrogen solution produces growth response similar to that of urea prill application, and (4) light nitrogen fertilization in young Douglas-fir reduced aphid populations by about 50 percent. Nutrient status and fertilizer responses are still highly variable but information such as this is a leading toward better understanding. (847)

626. To maintain rapid growth of black walnut trees we need to know when and how to thin plantations. A stocking guide which is based on crown competition factor provides a biologically sound, flexible tool for guiding thinning operations. Large benefits can be derived by planting more trees than are needed

and by selecting the better individual trees as the plantation develops. (866)

627. Quality of pin oak for lumber is low because of dead branches that persist for many years. In a study in Missouri, 12 years after pruning, bole quality was improved. Although there was some epicormic branch sprouting, almost all sprouting on the pruned trees occurred within the first 4 years after pruning. (859)

628. To maximize wood yields intensive cultural methods and improved genotypes must be explored and defined. Very short rotations (3 years) of *Populus* species grown at spacings of 9 × 9 inches produced over 4 tons/acre/year of dry weight wood in northern Wisconsin. Although nearly all wood quality traits varied between clones, they were well within the ranges reported for *Populus* pulpwood. Differences in yield between two clones demonstrate the potential for making gains through genetics. This maximum fiber yield approach appears to be an alternative for meeting increased demands for pulpwood in the Lake States. (233,844,845,846)

629. The supply of high quality yellow birch logs has dwindled in recent years and ways to speed the growth of existing trees are needed. Yellow birch saplings released before age 16 developed larger crowns and increased diameter growth. Crown release or selection thinning of saw log-sized trees yielded a 50 percent increase in diameter growth over unreleased trees. Fertilization increased lateral branch elongation in the upper part of the crowns, but did not increase diameter growth during the first 3 years. Thinning yellow birch stands in the Lake States can be expected to reduce rotation age and alleviate the problem of high quality material. (850,851)

630. The nutrient cycle holds the key for continuously productive management of loblolly pine plantations. The quantity of nutrients taken from the cycle through harvest and the supply available for subsequent rotations depends upon the fertility of the soil, length of rotation, and the proportion of the tree removed. Twice as much N is removed when all aboveground portions of loblolly pines are removed than with conventional pulpwood harvesting to an 8 cm top. Young, fast-growing trees utilize available nutrients faster than older trees. Total tree removal and short rotations remove more nutrients than conventional harvesting and long rotations. On some sites, the consequence may be a decline in productivity and a need for fertilization. Forest managers must take the nutrient cycle into account if successive rotations are to be profitable. (746,753,-754,872)

631. Interplanting is sometimes used to bolster stocking, especially under cost-sharing programs that require minimum stocking for payments. Results on the Holt Walton Experimental Forest in south Georgia show that slash pine plantings originally spaced 12 × 12 and 15 × 15 feet cannot be successfully interplanted 1 year later. In two of nine plantations, interplanted trees contributed only 267 cubic feet of merchantable volume at age 25, compared to 2975 cubic feet for originally planted trees. In effect, planting costs were doubled to yield only 8 percent additional volume. Forest managers should avoid wasteful investments in interplanting. (925)

632. A soil herbicide treatment is needed that will eradicate dense stands of brush on upland pine sites in the South. A test with bromacil and tebuthiuron applied to hardwoods on an upland sandy loam in central Louisiana at 4, 8, and 12 pounds per acre showed that tebuthiuren gave higher kills of most hardwood species at all rates, but was also more lethal on loblolly pines planted 12 months after than bromacil. Pine survival was lower with small pellets of tebuthiuron applied broadcast than with large pellets applied in a grid pattern. Results are of interest to researchers and to land managers attempting to develop appropriate site preparation measures for southern pinelands. (864)

633. Dicamba is not used widely as a foliar spray on hardwood brush because it is ineffective on a broad array of species. Absorption, translocation, and breakdown of the herbicide were studied with several species to help explain erratic kills. High rates of application damaged treated foliage and reduced translocation. Low rates moved freely in the plants, but were decarboxylated, complexed with sugars and amino acids, and lost from the roots into the soil. Treated plants were not killed. The greatest potential use for dicamba in foliar sprays appears to be in mixtures with other herbicides such as 2,4,5-T or picloram. (841)

634. Information on the behavior of natural hardwood regeneration on clay soil in southern bottomlands is very limited. Nuttall oak and associated hardwoods can survive under an almost complete forest canopy for as long as 15 years. Many will respond to release after 9 or more years in the understory. Sprouts and advanced reproduction of green ash, particularly, will grow from 30 to 50 percent faster in height than Nuttall oak seedlings. Dominant trees of faster-growing species may have to be killed if Nuttall oaks are to be favored. Managers can use these findings for wise selection of silvicultural systems. (857)

635. Effective and inexpensive methods are needed to thin pole-size hardwoods and control undesirable hardwoods. In tests in northern Arkansas, Tordon 101 and 2,4-D were injected into a large number of hardwood species during the dormant and growing seasons. Both chemicals were effective when applied to all test species but red maple, ash, and dogwood during season. Tordon was generally more effective than 2, 4-D and tended to cause crown kill sooner after dormant season application. These results will help land managers determine effective methods of hardwood vegetation control to meet specific objectives. (854)

Animal damage

636. Deer use is known to be associated with clearcutting practices in the coastal Douglas-fir forests, but the period of deer influence in these clearcuts hasn't been known. A study of 1- to 10-year-old clearcuts in these forests indicated that deer use peaks shortly after logging and declines thereafter. High levels of deer use were associated with reduced height growth and stocking of Douglas-fir regeneration, but moderate use appeared to have little adverse impact on the trees. This information helps wildlife managers and foresters adjust their management practices to meet mutually agreeable objectives. (792)

637. Little is known concerning the impact of animal depredations on direct-seeded black cherry in the southern Appalachians. Depredation of spot-seeded black cherry proved light and spotty in a series of trials repeated for 3 years in 10 cutover stands on the Cumberland Plateau. Protective screens increased seedspot stocking to 90 percent over the 81 percent obtained with unprotected seeds. Foresters and landowners can seed

black cherry in this region using nonrepellent treated seed with expensive screen protection. (799)

Growth requirements

638. Forest managers have lacked guidelines for dealing with the complex of insects associated with forest residues. Recommendations have now been synthesized from published information and operational experience, tailored for specific pest problems and land management situations, and compiled in one reference. The forester now has advice on how to manage residues to avoid pest problems. (526)

639. Engelmann spruce has been difficult to regenerate in its harsh subalpine environment, and physiological clues may help explain and overcome this problem. In recent research, water stress in spruce seedling roots and shoots was affected by soil temperature and net radiation. For example, at soil temperatures of 10° to 15°C, xylem pressure potential of spruce stood at about −10 bars, while at soil temperatures of 0 to 5°C, the potentials decreased sharply to −20 bars, even though adequate soil moisture was available. Xylem pressure potential was correlated with net radiation only when soil temperature was above 7°C. This study provides a better understanding of how environmental factors effect water stress in spruce and provide a basis for further study of spruce physiology. (775)

640. To study root initiation in forest trees, we need to develop stabilization techniques to overcome rapid losses of enzyme activity and ways to determine the amount of protein hydrolysis. A method was discovered for alleviating decay of dehydrogenase activity in crude extracts by partially removing the phenolics and chemically reducing the quinones. A new method of measuring protein hydrolysis using radioactive iodine [125i] is also faster and more sensitive. Previously difficult or impossible experiments with protein hydrolysis and dehydrogenases can now be performed. (770,772)

641. The usefulness of the wood of Douglas-fir and lodgepole pine depends on the variation in wood density within the annual rings. A new interpretation of the actual variation of specific gravity with growth rings was derived by comparing both X-ray and densitometric equipment and light microscope equipment. X-ray densitometry was confirmed to be the most rapid and efficient method of assessing wood quality. (766)

642. Forest management recommendations can generally be more complete when we understand the physiological phenomena that are operating. Although diameter growth in sugar maple increased with thinning, the foliar nutrient concentration decreased. The decrease is attributed to dilution. Fertilized trees generally had higher nutrient concentrations but they did not grow any more. These results suggest that release sugar maple poles will grow rapidly with foliar nutrient concentrations lower than those considered optimum for species in the Northeast. (869)

643. To understand wood formation, it is necessary to study the development of primary and secondary vascular systems. Analysis of serial microsections in *Populus* shows that the primary system is organized in a precise and predictable pattern. Procambial stands arise from older leaf traces below and develop toward the apex. Subsidiary trace bundles, which then develop downward from the base primordium, are the earliest progenitors of wood formation. Vessels arise within the base of a developing leaf and differentiate as metaxylem vessels in the primary body and as secondary vessels in each of its three traces. The structural vessel system that develops downward in the stem under the influence of a developing leaf will later serve that leaf as a functional water-conducting system. (778,779)

644. To understand the development of leaves in cottonwood, we need to know what happens to the major chemical fractions of the photosynthate in both young and mature leaves. For cottonwood leaves, the relative importance of imported photosynthate decreases as the leaf matures. There is considerable compartmentalization of imported and local photosynthate that varies with the stage of development. The precise physiological development that occurs in cottonwood leaves also helps in understanding wood formation. (767)

645. Few data exist on the growth and development of natural green ash stands on which to base silvicultural recommendations. In the Georgia Piedmont, green ash occurs naturally in pure, even-aged stands on poorly drained, silty flats. Total basal area carrying capacity on these sites is about 160 sq. ft. per acre. Volume growth averaging 39 to 65 cu. ft. per acre per year is primarily related to stand age. The pioneer nature of green ash indicates it is adapted for plantation management systems or natural regeneration or clearcut areas. (826)

646. Reduction of the spruce-fir forests of the southern Appalachians by 1920 stimulated research to find coniferous species that would grow well on the cutover land. Among 18 erotic and two local species planted on the slopes of Clingman's Peak from 1923 through 1931, Norway spruce, red spruce, and red pine have best survival, height, diameter, form, and vigor. The results also indicated that reforestation with silver fir and Japanese larch may have an important place in reestablishing the forests of the southern Appalachians. (787)

647. Unsatisfactory growth of yellow-poplar seedlings on many Cumberland Plateau forest sites in Tennessee has been attributed to recurrent soil water deficits during the growing season. Yellow-poplar seedling growth was inhibited at soil moisture tensions less than 15 bars, the permanent wilting point for most soils. Height growth was reduced, root development was drastically inhibited, and the seedlings wilted when tensions averaged 4 bars. Soil moisture content below 20 percent of available water is likely to be inadequate for newly planted yellow-poplar seedlings. Researchers and tree planters attempting to match species and site can benefit from these data. (780)

648. Poor control of substrate moisture levels has been reported to be a major contributing factor to variations in germination test results. Seven levels of substrate moisture were tested on seeds of four spruce species at the Eastern Tree Seed Laboratory in Georgia. All four spruce species proved tolerant of a wide range of moisture levels between 23 and 88 percent of the waterholding capacity of cellulose wadding. This information will help define optimum testing conditions and provide more uniformity between laboratories. (918)

649. Little is known of the relationships between water stress and cambial activity in southern pines. A study of 2-year-old loblolly pines in southern Arkansas showed that tracheid production was slower, fewer latewood cells formed, and latewood comprised less of the annual ring under simulated drought than under low soil moisture stress. The onset of latewood cell production, which occurred in early July, was little influenced by water stress. Trends in wood formation at the base of the live crown were similar to those at breast height but were less well

defined. This information is valuable to scientists studying the basic physiology of wood formation. (783)

650. For regenerating upland hardwoods, we need information on establishment and growth of trees following various cutting methods. In a study involving removal of overstory, species composition following cutting was not closely related to cutting intensity. On the other hand, subsequent height growth was strongly affected by cutting intensity with greatest growth on the clearcuts. Some difficulties associated with regeneration of oak after heavy harvest cuttings may be related to the relationship between time of budbreak and canopy removal (see 302). (781)

651. Growth regulation in plants has been hampered by a lack of knowledge concerning whether IAA oxidase activity arose from a separate or multifunction enzyme. Research evaluation revealed that IAA oxidase activity is one function of a dual catalytic enzyme. Optimum assay conditions were found using criteria of maximum initial velocity of oxygen consumption together with the optima for pH, p-coumaric acid, and hydrogen peroxide. These developments have international significance in growth-regulation research. (769)

652. Selection of Douglas-fir for various climatic regimes depends in part on the understanding of the phonology of budburst in the spring. Results from a study showed that under natural flushing conditions, date of bud burst is mainly a function of spring temperature, but occasionally also influenced by winter chilling and photoperiod. Development of these interrelationships in quantitative models would guide greenhouse operations for optimizing seedling growth and for predicting effects of seed transfer. (764)

653. The control of cambial activity and wood cell differentiation by growth hormones is not well understood. An isolated stem-segment culture technique was used in studying that control. When stem segments of *Pinus silvestris* were perfused with a defined culture medium under sterile conditions, their cambia produced new cells for as long as 15 weeks. With this technique, segments can be sacrificed at any time and studied anatomically. Effects of auxins, other hormones, and metabolites also can be studied in a controlled, isolated system. (790,791)

654. Many organisms, including trees, exhibit biological rhythms of nearly invariant periods and show well defined structural patterns of near uniform distances between repeated features. A possible explanation for this, based on biophysical and mathematical interpretation of extensive studies of the cellular basis and wave characteristics of variously "figured" woods, is advanced. A model system is proposed in which morphogenic waves of varying lengths, but similar periods, interact to form standing wave envelopes that serve as a basis of morphogenic maps. These maps are seen as underlying both patterns and rhythms in organisms. This idea is of wide theoretical interest. (774)

655. The vegetative reproduction of desirable lines of trees by means of cell cultures and embryoid formation is of great potential value. *Pinus gerardiana* cells continuously cultured in a liquid euspension system grew into callus masses when plated onto agar medium under specific conditions. When the callus was transferred to agar media supplemented with coconut water and hormonal substances, some root and shoot primordia differentiated. Extension of these techniques may lead to new methods of propagating pine asexually. (776)

Growth and yield

656. Determining management strategies for understocked stands has been among the most difficult decisions facing foresters. A stepwise process has been worked out for attacking this problem which includes describing the stand condition, determining the cause of understocking, and estimating and comparing costs and benefits of remedial actions. Utilization of this procedure can lead to sound decisions—maximizing timber production and other social benefits—on understocked areas by fitting uses to site capabilities. (932)

657. Stand development data for virgin forests are needed as benchmarks to compare stand changes over time without map's influence. Ten periodic inventories of an unburned virgin tract of southwestern ponderosa pine near Flagstaff, Ariz., have yielded growth and mortality data on more than 3,000 trees. Fifty years of change on this 80-acre tract are documented by: (1) Individual tree records, (2) 2.5-acre subplot summaries of basal area and tree count, and (3) composite stand and stock tables. This information should be useful in modeling stand development and also as a data source for research and teaching. (916)

658. Managed stand yield tables are needed for specified combinations of site quality, frequency, intensity of thinning, and utilization standards in the spruce-fir forests of the central Rockies, Procedures for computing the wood yields of managed even-aged stands of spruce—fir, as well as information needed to determine the influence of timber management practices on other forest resources, are now available. The new procedures enable the land manager to examine probable results of his operations in spruce-fir stands, study the effects, and make necessary changes before starting the operation. (915)

659. Assessing the growth potential of a young plantation is a necessary first step when deciding whether to invest time and resources in intensive culture. Site index predictions (height at age 25 years) for plantations between 5 and 13 years of age may be in error by more than 6.5 feet for one-third of the plantations, but should be within 5 feet for two-thirds of the plantations older than 13 years. Graphs are presented that can be used by the walnut manager to determine site index for young plantations on shallow floodplain soils and on deep floodplain or upland soils. (929)

660. What is the growth and yield potential for European black alder interplanted with black walnut? In a study on a good site in southern Illinois, European alder produced 3-1/2 tons of dry matter per acre per year during the first 9 years. Dimension parts sawn from 6-foot bolts 9 to 12 inches d.i.b. at large end compared favorably with other hardwood species. If spacing and planting time of the European alder can be adjusted so that it does not overtop the walnut, it may be a useful interplanting species. (931)

661. If the age of an individual tree in a group of even-aged oaks differs by 4 or more years from the mean age of the rest of the trees, errors in measured site index occur. Younger, shorter trees tend to grow faster in height than older surrounding trees, and older, taller trees tend to grow slower than younger surrounding trees. All trees grew about the same in height when heights were equal. Measured site indexes using such age-deviant trees were in error by about 1 foot for each 3 years of age deviation. Application of this correction factor will result in more accurate determination of site index for oaks. (930)

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662. Repetitive determinations of site index from conventional curves or tables is time consuming and subject to error. Formulas for computing site index have been derived from recently published site index tables for black, white, and scarlet oak in Missouri. Using these formulas, site indexes for large numbers of trees can be computed quickly and accurately by an electronic computer. (933)

663. The growth and yield of natural stands of slash pine can be altered greatly by thinning, and forest managers have difficulty choosing the thinning regime best suited for their particular stands and management objectives. A technique developed using previously published data compares growth and yield of slash pine stands on various site indices and at various ages for different thinning regimes at varying density levels. Total yield at rotation end is presented for all trees as pulpwood and as multiple products—board feet, slabs and edgings, kerf, and cordwood. The examples presented can be used in developing management programs based on product objectives and methods of operation. (919)

664. There are no published data that compare yields from seeded stands with yields from comparable planted stands. At age 22 years, average d.b.h., basal areas, and cubic volumes of plantation loblolly pine in Louisiana were slightly lower in the seeded stands than in planted stands. Statistical comparisons could not be made, however, because the plantations were not replicated. Despite the small advantage in growth and yield planted pines had over seeded pines, these results show that direct seeding is a reliable and profitable alternative to planting. (825)

665. Silage sycamore offers an opportunity to reduce rotation age and possibly increase yields of fiber for pulpwood. Sycamore cuttings were planted at 2 × 5 foot and 4 × 5 foot spacings in highly productive alluvium and harvested on 1-, 2-, 3-, and 4-year cycles. Yields were highest from plantings spaced 2 × 5 feet apart and from harvests at 2, 3, and 4 years. Growers in the Midsouth can increase yields from coppice sycamore by reducing spacing within rows, realizing that costs of establishment may offset this advantage. (926)

666. Information on the relationship of diameter and volume growth to initial spacing in cottonwood plantations on Mississippi River alluvium is lacking. Cubic volume growth in unthinned 10-year-old plantings in Mississippi varied from 2.8 to 3.4 cords per acre per year where initial spacings were 4 × 9, 8 × 9, 12 × 12, and 16 × 18 feet. Two thinning treatments did not increase yield. Average diameter increased as spacing increased. These findings will be valuable to foresters in selecting an initial spacing, evaluating the need for and timing of thinnings and prunings, and predicting volume production over time to meet specific management objectives. (927)

667. Little is known about the effects on tree survival and growth of careless cultivation that leaves covered and broken sprouts in cottonwood plantations along the lower Mississippi River. Covering cuttings with soil and breaking new sprouts from cuttings during early cultivation reduced survival by 30 to 70 percent. Undamaged surviving trees grew 30 to 100 percent more during the first year than those covered and/or broken. Cottonwood growers now have a measure of the importance of careful cultivation. (794)

Forest measurements

668. Rings in aspen wood are difficult to count and measure accurately. This operation can be made easier by first making a smooth shaved surface, then oven drying for 48 hours at 100°C, and finally moistening the surface with a 4 percent solution of pentachlorophenol wood preservative in either kerosene or mineral spirits. With this technique, even very narrow rings can be seen under a binocular microscope. (949)

669. Experimental work in the crowns for forest trees can now be done cheaper and safer with an inexpensive crown-access apparatus developed on the Fort Valley Experimental Forest. The versatile rig is stable, durable, quickly moved from tree to tree, and easily removed from the truck. Although designed specifically for making nondestructive inspections of flower and conelet development and cone collection, the platform without ladder is also useful. (943)

670. Stocking standards for assessing forest regeneration in the western forest regions often have been set as an arbitrary combination of plot size and management policy. A stocking scale has been developed to evaluate several stocking goals while using a single plot size. The new stocking scale should facilitate more rational assessment of forest regeneration establishment. (947)

671. Growth patterns are poorly described for many tree species, and there is a continuing need for accurate site index curves and yield tables. A comprehensive handbook has been prepared which presents step-by-step instructions for tree stem analyses. It details field procedures and computer analyses which provide stem profiles, height-age graphs, and cards and data lists for conifers up to 800 years of age. These instructions enhance the usefulness of the stem analysis research method in obtaining growth information and will be a valuable reference for forest managers. (941)

672. More efficient procedures are needed for handling stem analyses for obtaining growth information from old-growth forests. A stem analysis procedure has been developed that includes special techniques needed for old-growth trees in the high-elevation mixed forests of the Cascade Range in Oregon and Washington. A supporting computer program analyzes data and provides graphic and tabular tree descriptions. These provide the basis for site index curves and individual tree volume growth estimates in old-growth forests. (941)

673. Many reported tests of accuracy of instruments used to measure trees are worthless because, without real knowledge of measurement accuracy, no evaluation of instrument costs and benefits is possible. Only results of repeated measurements by trained observers give valid estimates of measurement error. Measurement studies in the Pacific Northwest show that tests should include basic instrumental and observer accuracy under easy measuring conditions, and then progress to the forest where accuracy is more difficult because of impaired visibility. These evaluations help those involved in forest measurements to recognize types of measurement error with optical instruments, biases, and related measurement theory. (937)

674. There are unanswered questions worldwide about the adequacy of techniques used to evaluate newly-established stands. Tree seedlings need to be inventoried one or more times during the regeneration period to determine if reforestation efforts have been successful. This review raises questions that should be resolved regarding objective evaluation procedures

for setting stocking standards, making allowances for tree losses in developing stands, and developing intensity levels for field sampling. (948)

675. Measurements with optical calipers and rangefinder dendrometers may not be too meaningful if the tree is out-of-round or viewed from one direction. Cross-section measurements of a large sample of felled coastal Douglas-fir trees revealed that out-of-roundness was greatest at stump height. The longest diameter at any height in the tree was randomly oriented on moderate and steep slopes, and only slightly related to direction or slope. Out-of-roundness is not likely to bias volume estimates in large-scale cruises, but individual tree bias can be appreciable. Managers dependent on accurate volume estimates should consider this information in tree analysis work. (950)

676. Increased aspen utilization by tree-length and whole-tree harvesting and weight scaling have created a demand for methods to estimate volumes and weights of whole trees and stands. From data collected in the Lake States, tables have been developed which estimate gross volume, green weight, and dry weight for individual trees, diameter classes, and entire stands. Weight scaling will improve utilization of aspen in north United States. (946)

677. Years and sometimes decades must pass before the effects of specific management practices can be measured as changes in yield. Simulation modeling provides a useful alternative to waiting for results. A model which was developed to estimate production of loblolly pine plantations based upon synthesis of data on input, cycling, and loss of nitrogen indicated that the cycling rate was a critical area in need of further research. The model can also be used to predict effects of cultural practices such as thinning, harvesting, fertilization and burning on the distribution of nitrogen in the system and on plantation productivity. (956)

678. Foresters have continued to make wide use of the site index curves in USDA Miscellaneous Publication 50 but until recently they were generally forced to make laborious graphic determinations from these curves. A FORTRAN program has now been written which utilizes recently fitted site index equations for the four major southern pines to compute site index (or height) arrays for any given index age and arrays of integer age and height (or site index). This program will facilitate use of these curves and benefit activities ranging from operational management planning to growth and yield research analyses. (939)

679. Estimation of stem volume in standing trees is one of the fundamental problems of forest mensuration. In recent comparisons of measurements with two dendrometers, volumes obtained from Spiegel Relaskop measurements were only 1.6 percent higher than those based on Barr and Stroud measurements. The relaskop is more efficient for timber cruising because it is compact, relatively inexpensive, and reads directly, thereby lessening the chance of a reading error. The Barr and Stroud is recommended for precise measurement of diameter and volume increment. Foresters can select the instrument best suited to meet specific objectives. (951)

680. To make decisions concerning ecosystem management, we need to know how much organic matter can be safely harvested as a crop. To make estimates of the timber fraction of ecosystem production, a system was developed using a matrix of primary units of measure. The primary matrix is a set of values for volume, bole surface, and length arrayed by top diameter of stem segments and aggregated from the largest to the smallest. The system can be used to describe and compare differences among forest stands. (934)

681. The kinds of information and capabilities needed to develop management plans for large acreages of wildland are becoming increasingly diverse and complex. A large scale Wildland Resource Information System (WRIS) has been developed for this purpose in California. WRIS is a computerized production tool for collecting, processing, storing, retrieving, updating, and displaying geographic data. The system can be useful in integrating and making the most of resource information under the manager's control. (944,945)

Management planning

682. Northern hardwood all-age forest growth is difficult to predict and methods to use growth data for practical situations have been met with difficulty. Using data from the Upper Peninsula Experimental Forest in Michigan, a series of differential equations was developed. The equations distribute growth by size class and growth components, with resulting tables which are useable directly by forest managers. (954)

683. When faced with interpretation of complex sets of data involving large numbers of interrelated variables about which there is little *a priori* knowledge, a system called principal component analysis (PCA) offers help. The system was recently field tested with data from white spruce and red pine provenance trials in the North Carolina region. Some of the advantages of PCA included: (1) Reduction of the number of variables by deletion of extraneous variables; (2) ordination of variables as an aid to the interpretation of multivariable data; and (3) to supplement regression analysis for the identification of biological variables for further experimentation. (953)

684. Spacing of planted trees is one of the more important decisions land managers face. Measurements of 15-year-old loblolly plantings in the Piedmont of South Carolina show that more total volume was produced at spacings of 6×6 and 8×8 feet than at 10×10 and 12×12 feet, but that the wider spacings produced trees of larger diameter. Product objective and the probability of thinning should be considered before selecting the spacing for loblolly pine plantations on productive Piedmont sites. (917)

685. Some current thinning practices should be changed. Often, slash pine plantations grown on 25- to 30-year pulpwood rotations are thinned at about age 15 because of seemingly high basal areas, but no thinning or thinning a few years before the intersection of the current and mean annual growth curves would have produced more pulpwood. Maximum production of sawtimber in rotations of 35 years and under is obtained by removing pulpwood in a thinning at about age 20 and carrying only 200 to 300 trees to final harvest. To maximize board foot yields in rotations of 40 or more years, heavier stocking should be carried, with two or three thinnings before final harvest. These guides should maximize production of pulpwood and of large wood products for slash and other pine species. (920)

686. No available information compares yields from plantations of northern conifers with those from naturally regenerated aspen. Yields at age 40 compared in central Minnesota showed volumes were highest for red pine (408 cubic meters and 147 tonnes per hectare), progressively less for aspen, jack pine, and

white spruce, and lowest for black spruce (183 cubic meters and 70 tonnes per hectare). Land managers may anticipate similar variation in yields attributable to species when reforesting similar sites. (957)

Naval stores

687. The prospect of substituting oleoresins for petrochemicals as sources of energy prompts testing the potential of conifers for paraquat-induced lightwood production. Tests showed that oleoresin yields from loblolly pine may exceed even those of slash and longleaf pine, thereby adding millions of forested acres to the potential land base for lightwood. Eastern hemlock showed only minimal resin soaking in response to treatment. The potential for lightwood production can influence a land manager's selection of species and later management decisions. (1032)

688. Two systems of producing lightwood oleoresin appear to be financially attractive with southern pines—a single wound treatment to produce lightered pulpwood trees for kraft pulping, and a multiple wound system to concentrate oleoresin in the lower bole for solvent extraction on pre-extraction of pulpwood chips. On the basis of present biological and economic information, it is virtually certain that the lightwood technique will be highly profitable, and, consequently, oleoresin production in the South may be expected to increase dramatically. (1037)

689. Chipping slash pine for production of gum naval stores generally reduces rates of volume growth. Slash pines chipped 8 years had less inside bark volume and slightly thicker bark than trees chipped 2 years, yet their d.b.h.'s were similar. Standard volume tables would not detect differences in volume inside bark. Changes in family mean tree volumes in response to chipping were only slightly correlated with amounts of gum produced. Several high gum-yielding families showed little or no reduction in volume. Reduction in volume may be a response to wounding independent of gum yield. If response to wounding is heritable, it might be possible to select trees for both gum yield and volume production. (1031)

690. If gum naval stores is to survive as a viable industry, it must mechanize and reduce labor costs. Too much labor is consumed in handchipping faces to induce resin flow. A power tool developed at the Southeastern Forest Experiment Station in Olustee, Fla., not only does the job better than by hand, it is much quicker and consequently cheaper. A virtually identical tool is proving its worth in chemical inducement of lightwood. In both uses, this tool will help relieve energy shortages by increasing oleoresin production. (1030,1033,1036)

691. Oleoresin increases caused by chemically induced lightering are difficult and costly to assay because of erratic, nonhomogeneous lightwood formation in the bole. Research in northern Florida showed that oleoresin content cannot be adequately determined using specific gravity differences between treated and untreated portions of slash pine stems. Chemical analysis revealed that oleoresins are measurably increased beyond areas of visible lightwood. These findings were most useful in determining the sampling intensities required and in devising new analytical techniques to attain necessary accuracy in oleoresin yield estimates. (1035)

BREEDING IMPROVED TREES

Inherent variation

692. Since genetic variation is associated with geographic distribution, seed zones need to be delineated to prevent off-site planting problems. To accomplish this in the Great Plains, the region was divided into 86 seed collection zones on the basis of soil, topography, water, and climate. Future provenance tests will be used to determine needs for adjustments in zone boundaries. By following these guides, land managers should be able to better prevent disastrous losses caused by genetically maladapted seed. (965)

693. Browsing of Douglas-fir, resulting in reduced height growth and stocking levels of Douglas-fir regeneration, is a serious silvicultural problem in the northwestern U.S. coastal forests. Studies in Oregon and Washington indicate that animal browsing activities are related to tree genotype, that there is a positive association of foliar chlorogenic acid content with susceptibility to browsing, that levels of this acid were heritable, that foliage of browse-resistant classes of Douglas-fir emitted greater amounts of volatile terpenes than that from susceptible genotypes, and that terpene levels and composition are heritable. All of these findings have application in breeding Douglas-fir for resistance to browsing. (798)

694. To increase efficiency in tree breeding programs, it is desirable to be able to predict performance at a later growth stage with data from nursery results. Until these correlations are computed, there is no certainty that this can be accomplished. In slash and loblolly pine, correlations between nursery and 5-year heights were low and nonsignificant. Genetic gains made through progeny testing depend on establishment of field plantations. (979)

695. Although Tamarack has potential for short rotation pulpwood in the Lake States, adequate information on which seed source should be used is lacking. Results from studies in Wisconsin indicate that growth gains are possible through proper seed source selection. Sources that grew well on one site also grew well on another, indicating little genotype x environment interactions. Increased production can result through proper seed source selection. (974)

696. Yellow birch is a valuable hardwood species that occurs over a wide geographic area. To identify superior individual trees and the seed source that will produce the fastest growing and best quality trees, provenance and progeny tests were established in Wisconsin, Michigan, New York, and New Brunswick. Northern sources tend to survive better than southern sources when planted in the more severe northern climates. There was no direct relationship between growth and latitude of seed origin, but some sources grew faster than others. Thus growth gains can be made in future breeding work through individual tree and seed source selection. (962,963)

697. To get the fastest growth and good stem form in black walnut plantations we need to determine the best geographic source of seed. In a southern Indiana plantation, trees originating south of the planting site were generally larger and had greater straight height than trees from the north. Trees from stands in North Carolina, Tennessee, and Kentucky should be included in walnut improvement programs for southern Indiana. (961)

698. In improvement programs involving black walnut, maximum gain depends on knowing the amount of variation, inter-

trait correlations, and gain obtainable by different selection methods. In a young plantation in southern Illinois, family selection for height, diameter, or straight height resulted in gain for all three of these traits, with a slight genetic loss for date of leaf flush. Family selection gave greater expected genetic gain than either provenance or mass selection. Black walnut seed orchard developers in eastern U.S. can use this information to help increase the future supply of high quality walnuts. (977)

699. Although black walnut trees grow rapidly on good sites, no strains have been selected for droughty sites. In a greenhouse test, seedlings from western Missouri and Kansas generally did not wilt as quickly as did those from southern Illinois and Kentucky, but in field tests, there were no differences in survival and growth between the western and eastern trees. In the future, black walnut selection work for drought hardiness should explore local and south-of-local sources. (960)

700. Although sulfate naval stores recovery is a highly profitable part of modern pulping practices, little is known about what gains might be expected through genetic selection. Wood samples from 20 wind-pollinated loblolly pine families showed that there were large differences in yields for ethanol-benzene extractions and turpentine. Trees that have large limbs and are rust-infected tended to have higher yields. Results will be useful in making marketing decisions and breeding plans. (969)

701. The discovery that paraquat can induce resin-soaking in slash pine is of interest to tree breeders because of the possibility that the response may be genetically controlled. In a test in Florida, 20 clones of slash pine treated with paraquat yielded more oleoresin than did the control. Although the extent of resin-soaking varied highly among clones, it was not correlated with gum naval stores yield of the ortets. Genetic selection for paraquat response would yield little or no gain. (988)

702. Although jack pine has been shown to be well-adapted to Nebraska conditions, growth and other traits are highly variable—probably due to seed source of planting stock. So a study was established to determine which seed origins were best adapted for use in Nebraska and the Plains. Survival of trees from all 28 geographic origins tested was good, and height growth for sources varied from 7.6 to 14.3 feet, with southern sources generally taller. The taller sources also have the best form and are recommended for planting in the central Plains. (985, 987)

704. While ponderosa pine is native to and has been used extensively on the Great Plains for many years, performance of planted trees has not always been consistent. Six-year survival and growth data from a 78 origin provenance test in east-central Kansas indicates that growth is better from lower elevation sources. A seed collection area in north-central Nebraska and adjoining South Dakota is recommended for Kansas. (966)

705. Conifer species that will survive and grow are needed for establishing plantations on the Great Plains. Species with potential for good survival and growth need to be studied for provenance variation. In eastern Nebraska, an 11-year-old study of 52 rangewide seed sources of red pine revealed that there were height differences among provenances. A fast-growing origin from Quebec is recommended, and seed supplies are being acquired to improve plantings in eastern Nebraska. (986)

706. As planting and intensive culture of *Populus* clones becomes more widespread, the physical and chemical properties of the wood become increasingly important in clonal selection. In a study of 18 *Populus* hybrid clones in Wisconsin, the percentage of lignin and wood sugar, specific gravity, and growth ring width varied widely. Growth rate did not affect the chemical composition of the wood. And, it appears that clones can be selected combining rapid growth and desirable chemical composition traits. (967,1320)

707. Progeny testing of hardwood tree species has been limited and associated problems have been unique. A summary of papers dealing with progeny testing problems is presented in Proceedings of IUFRO Working Party on Progeny Testing. Researchers and tree improvement personnel can use this to increase efficiency in their tree improvement programs. (970)

708. Seed yield is a vitally important factor in getting genetically improved stock into plantations. In a 9-year study of slash pines, conelet and cone yields showed a weak tendency to increase with increasing d.b.h., tree height, percentage of live crown, and tree age. Rainfall in June stimulated conelet production the following spring. Temperature did not affect yields. Previous fecundity was the best indicator of a tree's capacity to produce conelets, cones, or seed. Number of seed per cone was not related to cone yields per tree or percentage of sound seed. These results will aid seed orchard managers in increasing seed production as well as researchers in directing new research efforts. (992)

709. To increase the growth of loblolly pine in the South, silvicultural and genetic manipulation is needed. In a study in Arkansas and Louisiana, simple selection of large seedlings in the nursery bed resulted in larger trees at age 9. Even greater gains can be expected by carefully choosing the parents. In loblolly pine at age 10, average volumes of wind-pollinated plus-tree progenies exceeded those of woods run progeny by 18 percent. Additional gains can also be made through proper geographic seed source selection. These results will influence management decisions concerning investments in tree improvement. (971,972,973)

710. Virginia pine is a valuable and desirable source of pulpwood in the southern United States, and information on potential for genetic improvement is needed. A study in Virginia indicates that total wood mass in 8-year-old trees is subject to only minor genetic influence. Although there were differences in nutrient concentration, most of this was environmental rather than genetic. Tree improvement programs can now be adjusted to anticipate the low expected gains. (980,983)

Insect-disease resistance

711. To quantify genetic gains in slash pine, it is necessary to compare progeny from selected and average parent trees. After 15 years of evaluation for survival, growth, and rust resistance, it is apparent that mass selection is an effective method for improving slash pine in Georgia. Individual selections from the best families will now be used as sources of material for advanced generation breeding, leading to still further genetic increases for slash pine in the south and southeastern U.S. (1003,1004)

712. To increase production in southern pines, methods are needed to reduce losses from fusiform rust disease, and, at the same time, maintain or increase growth. Hybridization looks promising for accomplishing this goal. Gains have been made by crossing high rust resistant shortleaf pine with the more rapid growing loblolly, followed by backcrossing and selection. For

further gains, future southern pine breeders need to establish more plantations of shortleaf x loblolly pine hybrids. (999)

713. Subjective estimates of mortality from prescribed burning for control of brown-spot needle blight are seldom reliable for making preburn surveys of infected longleaf pine seedlings. Results from a test fire in Alabama recommended burning when the average infection level on crop seedlings reaches 20 percent and the root collar diameters are between 0.3 and 0.7 inches for grass-stage and more than 1.5 inches for height-growth seedlings. This information will help schedule prescribed fires more effectively for mass selection of superior and disease-resistant seedlings and improve the vigor of newly regenerated stands. (1000)

714. Seed production from southern pine seed orchards is not fulfilling expectations. Female flowers of both slash and loblolly pine often die during the period from just before the flowers become receptive to about 3 weeks after pollination. Preliminary experiments in which loblolly pine flowers were inoculated with fungi isolated from damaged flowers of slash pine produced damage symptoms on the loblolly pine flowers. If damaging fungi can be identified and control measures found, benefits will accrue to southern pine seed orchard programs throughout the South and Southeast. (1002)

715. Genetic improvement of loblolly and slash pines depends on selection of strains that are resistant to fusiform rust. Loblolly pine from Livingston Parish, Louisiana, has been shown to be resistant and has grown well in central Mississippi, Alabama, and Georgia. Resistant trees can now be identified in artificially inoculated progeny tests, but because there is genetic diversity in the fungus, it is important to test trees against an array of inocula. Reliable resistant breeding programs and improved trees will result from this work. (995,996,1005,1007)

Tree breeding methodology

716. Geneticists use pollination for controlled breeding in tree improvement, but, since the pollinating season is short, a rapid procedure is needed. A simple and inexpensive pollinator was designed which is compact, waterproof, non-clogging, and requires only small quantities of pollen. This device has considerably increased the speed and ease of pollinating. (1008)

717. Self-pollination in seed orchards can result in seedlings with reduced vigor and steps should be taken to minimize selfing where it is a serious problem. In a slash pine seed orchard in Georgia, the occurrence of selfing, as estimated by chlorophyll mutants, was low and is not considered a serious problem. Gains from tree breeding efforts can be made without significant loss due to selfing. (976)

718. In developing genetically improved forest trees, we commonly use data for traits measured at only a single time, e.g., at age 25. However, we do not know if this is the most efficient approach. The form of the height growth curve as a composite trait was subjected to genetic analysis, with tobacco as an example. The results show that selection for whole growth curve functions is more effective than for size at a series of ages. To make maximum gains, tree breeders should consider economic growth functions as selection criteria, instead of size at one age. (1025)

719. Many ponderosa pine seedlings grown in California nurseries are too small to survive field planting. One approach to improving this situation is to collect seed only from parent trees proven to produce large seedlings. Wind pollinated families from stands selected in a variety of environments in the northern Sierra Nevada showed large within-stand differences. By nursery testing seed trees, and excluding seed from the poor performers in future years, there can be immediate gains in the size of planting stock and improvement of nursery efficiency. (1022)

720. For action programs of walnut genetic improvement to be effective, sound procedures for design and evaluation of superior trees are needed. As a result of many tests and much more experience workable procedures for evaluating selections have now been established. Tree improvement specialists in States, industry, and the National Forest System can benefit from the use of these new guides. (1010)

721. Maximum genetic improvement in black walnut is dependent on having correct estimates of environmental and genetic variation. By use of walnut twins (derived by splitting germinating seeds), efficient estimates of variation for growth and phenological traits were obtained. Amost all genetic variation was due to additive gene action, and family selection is recommended for walnut improvement programs in eastern U.S. (978,1023)

722. Black walnut trees usually grow very little the first year after transplanting. In a southern Illinois study, limiting environments were much more critical than genotypes in explaining the characteristic lack of first-year growth. Greater gains can be made by emphasizing site selection and amelioration than by attempting to breed trees that can withstand transplant shock. (1011)

723. Predicting genetic gain in tree improvement programs requires unbiased estimates of heritability. The correlation coefficient, used as an estimator of heritability, has biases in it which are related to number of trees per family and the coefficient of relationship among family members. Methods and tables have been developed to devise adjusted estimates based on number of trees per family and degree of selfing. (989,1015)

724. High soil fertility and good soil physical condition are required in pine seed orchards. Irrigation increased tree growth during the first 7 years; however, neither irrigation nor fertilization had a significant effect on tree size at age 12. A hairy indigo cover crop increased soil nitrogen about 250 pounds per acre during the first 5 years but did not increase tree growth. After the legume was shaded out, at about the 6th year, soil nitrogen began to decline and tree growth showed an increase on the cover-cropped plots compared to plots which were disked. Soil improvement by nitrogen fixation can possibly substitute for nitrogen fertilization. (1027)

725. Grafted seed orchards of lodgepole pine have been plagued by graft incompatibility losses. Anatomical evaluation showed that incompatible grafts had greatly reduced xylem growth in union zones. The internal incompatibility symptoms were correlated with scion overgrowth and needle chlorosis and could therefore be rogued, thus affording a considerable dollar savings in grafted seed orchards. (1012)

726. Identification and classification of deviate phenotypes would be useful in studies where gene markers are needed. In a comparison of isoenzyme characteristics in Douglas-fir, dwarfs were unique in that they had some bonds not found in normal trees, some bonds stain darker, and some bonds were missing. The zymograms furnish a useful means for chemically identifying dwarf variants, which may be used in studying pollen flight. (1013)

727. In genetics studies, it is sometimes necessary to store tree seed which segregates at germination for mutant markers. It is necessary that the mutant seed maintain its viability in long-time storage for as long as normal seed to provide original segregation ratios. Agricultural literature indicates that storage often selectively kills some mutants. However, an albino mutant used in experimental studies in Douglas-fir was found to store well for 6 years. (1029)

728. Graft rejection is a major problem in Douglas-fir seed orchards and will continue to be until highly graft-compatible rootstocks are available for general use. Improved laboratory methods have been developed for testing compatibility of Douglas-fir in the Pacific Northwest. Incompatibility can be studied and recognized and an efficient laboratory method for preparing stem sections has been devised and described in a new guide. (1018)

729. Casting acrylamide gel columns for electrophoresis usually requires depositing a water layer over gel solutions to achieve clean, flat surfaces. To offset attendant inefficiencies, a technique employing flatground disposable plungers was developed. The system reduces cost as well as expedites the many electrophoretic assays necessary for studying the genetic structure of plant populations. (1020)

730. Techniques for propagating select trees by rooting are needed for establishment of seed orchards. A new technique involving stem girdling and hormone treatment apparently forces accumulation of food reserves and callousing and has led to increased rooting success in slash pine. Multiplying clonal lines of improved trees for seed orchards and plantations is now possible. (1021)

731. Southern pine seed orchards frequently are fertilized to increase and maintain productivity, but questions persist concerning formulation and timing of application. Nitrogenous fertilizers proved most stimulatory to production of strobili and cones on young loblolly pine grafts in seed orchard tests in Mississippi with ammonium nitrate giving the best response. Mid- to late-summer applications quadrupled seed production. Such findings provide valuable guidelines for seed orchard managers. (1026)

732. When mating designs are complex or unbalanced, estimates of combining ability are difficult for the practical plant breeder. A FORTRAN computer program was recently prepared to show how general combining ability values from cross-, open-, and self-pollinated progeny can be derived from a single analysis. Using this program, more efficient analyses are possible. (1028)

IMPROVING USES AND PROTECTION OF WOOD

Utilization potential and processing of wood

733. A comprehensive summary of current information on bonding wood into dependable, long-lasting products is presented. Characteristics of wood that affect gluing are detailed, as well as types of adhesives and processes used for various conditions. This definitive source of information on adhesive bonding is useful to all the forest industries concerned with gluing of wood. (1304)

734. The assurance of long-term durability of plywood adhesives requires service testing over long time periods. A rate-process analysis method has been devised to evaluate, over shorter times, the long-range durability of several adhesives for Douglas-fir and yellow birch plywood. Using the short-term predictive test, it is concluded that the differences among adhesives, when in service environments, are due largely to their relative resistance to moisture rather than to their thermal instability. The methods described can be beneficial in selecting adhesive substrate combinations suitable for long-term structural performance. (1251)

735. The glue line of a glued wood product can be greatly weakened by damage incurred on the wood surfaces during machining and surface preparation. Crushed and torn wood cells break away easily when the glue line is stressed. Sawing damages surface cells more than knife-cutting. Planing or jointing produce stronger cell surfaces. Sharper tools cause less surface damage which again will result in stronger glued products. (1294)

736. Wooden houses should be repainted only after previous paint has weathered thin because paint failures tend to occur if the paint film is too thick. A simple test is described for determining whether an old paint surface will form a satisfactory bond with latex paint. Simplified instructions for repainting a house, including preparations of surface and application of paint, are included. This information is of broad interest to owners of homes and other wood structures. (1283)

737. Early selection of desirable genetic strains of trees is difficult because of the long times required to firmly establish characteristics of growth and wood quality. Aspen tissue, grown in the laboratory on synthetic medium, has been treated with growth hormones and the resulting effects on growth rate and cell characteristics observed. The associated changes in enzyme activity are quantitatively related to growth-rate, confirming the feasibility of using the measurement of enzyme activity for assessing growth rate and wood quality characteristics. Reliable early prediction of growth rate can aid geneticists in their selections of desirable strains of trees. (1313)

738. One alternative for improving the yield of solid wood from a log is to slice thick lumber with a knife (similar to veneer cutting) thereby eliminating sawdust. The effects of 17 different slicing process variables that have been determined are summarized. Guidelines are provided which will assist machine manufacturers in the design of a commercial thick slicer. (1287)

739. New forming and pressing techniques are required to make shaped structural products from reconstituted wood. The technique holding most promise for commercial production of an I-beam type shape maintains a level mat during the forming period by utilizing a low bulk density fibrous material for the web portion of the beam and alined flakes with high bulk density for the flange areas. Physical properties depend strongly on beam configuration and indicate that with proper engineering design and construction techniques, beams can be made to suit a variety of structural applications. (1249)

740. Forest residues provide a large potential raw material source amounting to nearly 9.5 billion cu. ft. annually. High quality structural particleboard can be manufactured from forest residues containing as much as 8 percent bark and 12 percent decayed wood. Manipulating processing techniques and particle alignment techniques allows a variety of performance specifica-

tions to be met. These studies are important in gaining acceptance of particleboards made from forest residues for structural uses. (1250,1305,1370)

741. Producers of hard maple have difficulty in consistently drying it to the normal light orange-yellow or white color desired for most products. The wood often tends to darken during drying. Research findings relate color development with variations in dry-kiln conditions. Colored material within the ray and axial parenchyma cells is related to the different discoloration types. Recommendation of drying procedures are presented which helps avoid dark coloration and the unnecessary waste of high quality hardwood. (1278,1279)

742. Common drying practices "overdry" most of the lumber in order to reduce the moisture content of the wettest boards to 19 percent, the maximum allowed by American Lumber Standards. The technological basis for an improved two-stage moisture equalizing treatment is provided. The first stage keeps the driest lumber from becoming too dry while continuing rapid drying of the wettest pieces. In the second stage, moisture is restored to the surfaces of the driest boards, while the wettest boards continue to dry. The use of recommended drying schedules can greatly reduce the costly losses during machining caused by excessive drying. (1280)

743. Southern pine sites usually have a substantial amount of small-diameter hardwoods mixed in with the primary pine species. Certain properties of the common hardwoods were determined in order to facilitate more extensive utilization of the hardwood biomass. Moisture contents of the wood and bark varied from roughly 50 to 150 percent. In most species, stemwood moisture was higher than branchwood and branch-bark moisture higher than stem-bark. Moisture reduces longitudinal permeability of the hardwoods. Ratios of the much greater longitudinal permeabilities to the lesser radial and tangential permeabilities were quantified. (1240,1241,1273,1258)

744. It is generally agreed that railroads of the Nation must expand their capabilities to contribute to the national good. Consequently, they must also substantially increase their rate of tie renewals if roadbeds are to be maintained in acceptable condition. While larger trees are becoming more scarce, faster trains and heavier loads will require that mainline ties average the large 7- by 9-inch size now in common use and larger. A logical source of wood for these ties is the enormous inventory of underutilized small hardwoods in the South, East, and Midwest. The process of dowel-lamination can permit manufacture of 7- by 9-inch mainline ties by laminating together two smaller pieces from logs with small-end diameters of only 8.3 inches—a size that is plentiful. The concept should be of value to the railroads, to suppliers of crossties, and to woodland managers. (1257)

745. Wood processing plants—though net consumers of energy—often have available sufficient quantities of green bark and wood waste fuel to make themselves relatively self-sufficient in energy; the problem lies in developing an adequate technology for economically burning such wet fuels. A process has been developed and described whereby green bark residual from southern pine lumber production can be direct-fired in a low-cost suspension burner and the heat used to kiln-dry lumber. The invention will substantially aid the industry to become self-sufficient in energy and at the same time solve a residue disposal problem. (1260)

746. Southern pine lumber—particularly that cut from small logs—tends to warp excessively when kiln-dried to the moisture content at which most of it is used (about 9 percent M.C.). A kiln apparatus has been developed for continuously producing dry lumber that is free from crook, bow, and twist. The kiln employs paired arrays of rolls in combination with rigid lumber-guiding and warp-restraining bars in such manner that lumber is totally restrained against warp as it moves continuously through the kiln. Through application of the principles embodied in this invention, losses attributable to warp in southern pine lumber can be largely eliminated. (1261,1262)

747. The preponderance of trees harvested in the U.S. in the future will be too small to yield lumber in long, wide, thick pieces. A method for producing multi-ply lumber from rotary-peeled veneers has been developed and patented. The system can supply structural lumber of virtually any length and width from logs of 4- to 8-foot length and diameters as small as 7 inches. The system involves gluing-up veneer plys with the grains aligned parallel. The yield of salable lumber product from logs is nearly 50 percent greater than the yield obtainable by conventional sawing processes. (1263)

748. For every cubic foot of pine on southern pine sites, there is about 0.8 foot of hardwoods. The hardwoods are often not utilized. The shaping-lathe headrig can be a key to utilizing these small, mixed hardwoods for pallets and lumber. The flakes formed by the lathe are suitable for structural particleboard, molded products, or pulp. Using mixed hardwood flakes from the shaping-lathe headrig, a structural exterior flakeboard was developed that is intended to be competitive with sheathing plywood. The shaping-lathe headrig is now a commercial reality. Much of the heretofore unutilized southern hardwoods now can become a commercial asset and be added to the timber inventory. (1259,1264)

749. In the years ahead, expanding kraft pulpmills in the South will have difficulty in harvesting sufficient wood to satisfy their requirements without major increases in the price of wood. A technological development that can assist in solving this supply problem is the invention of a machine that first severs lateral roots and then pulls southern pines from the ground like carrots. The machine harvests and bunches complete trees with taproot attached at a sustained rate of one to two trees per minute, thereby increasing pulpable wood volume harvested per acre by about 20 percent. Site preparation costs and hazard from beetles (and perhaps from root rots) should be substantially reduced by the new harvesting system. Dirt adhering to taproots presents a problem yet to be solved. Equipment manufacturers, procurements foresters, and land managers are benefiting from this research. (1266,1267)

750. After harvesting trees in pine plantations, logging slash is windrowed and burned. Subsequently, the site may be strip-plowed to control weed competition for new seedlings. Burning diminishes soil nutrients; skimming off top soil during the piling of slash greatly reduces fertility, and the bare soil rapidly loses moisture. A concept for site preparation is now advanced that calls for residual tops, branches, stumps, and underbrush to be hogged (cut up) by a new mobile wood-mulching machine as it slowly traverses the harvest site. Hogged material is spread as mulch between rows of planted trees via a belt system. A prototype mulcher has been built and tested. The procedure should reduce fire hazard, retain nutrients and soil moisture, suppress

weed growth, and improve regeneration and growth of new trees. (1268)

751. A common problem of the southern forest region is the underutilization of small diameter hardwoods. Medium-density fiberboard is a promising outlet for such wood, which can be supplied to mills in the form of "barky" chips. Boards of good quality can be made of small southern hardwood trees with bark included. Inclusion of bark diminishes modulus of rupture, tensile strength, and modulus of elasticity, but these effects can be countered by altering pressing schedules. The results of this study will be used by the fiberboard industry. (1310,1314)

752. The large volumes of forest residue remaining after timber harvest in the Pacific Northwest usually require treatment of some sort to meet multiple land management objectives. Over 200 guideline statements were developed by experts in various land management disciplines to help land managers apply the best technical and research knowledge in achieving these objectives. A unique keying system is provided for determining which guidelines apply to each planned management activity on a given site, within a given forest species association type. Application of these guidelines can materially improve the quality of management on both public and private forest lands. (1290)

753. Large trees that are defective or decayed are often not used even though a substantial amount of sound (usable) wood still remains. In order to economically utilize this type of tree and reduce waste, estimates of the lumber recovery that can be obtained from these large, defective, low quality trees are needed. Information on the obtainable lumber grades and volume yields will help forest-land managers, timber buyers, and timber processors more efficiently utilize this significant resource. (1308)

754. High quality hardwood lumber for the extensive furniture industry of the southeast United States is becoming more costly and more difficult to obtain. Available hardwood lumber must be used efficiently with minimal waste. Operations research has shown that the sequence of unit steps within the furniture parts manufacturing operation affected costs more than it did the efficiency of utilization of lumber.

An automated furniture parts mill has also been designed. Automation can improve the efficiency of lumber utilization by reducing decisionmaking, centralizing production of certain parts, and improving materials flow. (1232,1271)

755. Appraisals of standing trees ordinarily ignore the potential value of products such as bark, sawdust, and chippable residue produced when trees are processed into lumber at a sawmill. Estimates of these other products are important to the sawmilling industry and to people concerned with determining current timber volumes and values. Yellow poplar, longleaf pine, and shortleaf pine sawtimber trees were processed into lumber. From the sawmill data equations were developed to predict the weight of bark, sawdust, lumber (54 percent in each case), and chippable residue produced in the sawmill. This enables buyers and sellers of southern pine sawtimber to evaluate all the products they can expect to recover when processing trees through a sawmill rather than having an estimate of only lumber volume. (1242,1289,1303)

756. The geometry of the hardwood flakes going into particleboard has a profound effect on the ultimate strength properties of the board. Structural particleboards must meet rigorous strength specifications. Grain angles should be kept parallel to the length of the flake. Knife planing across the grain (ringhead planer) produces superior hardwood flakes. Utilizing hardwood wastes to make flake boards (flakes from ringhead planer) for structural applications can help alleviate demands on high quality softwood sawtimber. (1255,1256,1309)

757. Adequate penetration of chemical is necessary to successfully treat hardwoods with preservatives, fire retardants, stabilizers, or pulping chemicals. With some woods, penetration is difficult. Mechanisms and rates for movement of various treating liquids through resistant hardwoods have been determined. A mathematical description of the relationship between wood moisture content and moisture diffusion rate is presented. A mathematical model for the penetration of organic liquids is now available and can help predict the effectiveness of potential wood treatments. Contrary to softwoods, air-drying increases the permeability of hardwoods. Surface preparation or cutting method greatly affects the subsequent permeability of the cut surface. (1239,1240,1295,1296,1298,1238)

758. New methods of drying hardwoods to reduce wood waste due to splitting and cracking and to decrease costs are important needs of the hardwood processing industry. Freezing wood prior to drying reduces splitting and cracking. Pre-soaking of wood in a solution of natural wood extractives can also be beneficial in reducing wood damage and shortening kiln-drying times. (1244,1245)

759. Bark has been an undesirable by-product and usually has been burned as waste or dumped as landfill. With increasing concerns about environmental degradation, energy needs, and fiber shortages there is a need for more information on bark properties that can lead to its increased use. Data on percent bark by volume, percent of weight of bark and wood, and percent moisture content of bark and wood were determined for quaking aspen, black spruce, jack pine, balsam fir, and balsam poplar in northern Minnesota. These data can be used to develop specifications for boilers in which bark is to be used as fuel, and to calculate transportation and processing costs. (1274)

760. Large variations in wood density and shrinkage are very troublesome to users of Hawaii's most abundant timber tree species, Eucalyptus. Intensive sampling of wood indicated both specific gravity and shrinkage increased with distance from the pith and with tree height. Within-tree variation exceeds between-tree variation, therefore, Eucalyptus lumber can be sorted by its original location in the tree into groups of much more uniform specific gravity and shrinkage, which then can be marketed by Hawaii's sawmillers as wood types suited for specific uses. (1306)

761. A COM-PLY stud (two-by-four) is a composite sandwich type of lumber with a particleboard core between two double layers of southern pine veneers. Such studs have strength and stiffness equivalent to, or superior to, solid softwood studs and are also less variable and remain straighter in use. COM-PLY studs were used to build three demonstration homes. User acceptance was very satisfactory. Composite studs can greatly extend the supply of softwoods, since small tree parts can be used for the particleboard core. Hardwoods can also be used in the particleboard core. A prototype machine has been built to incorporate fiberglass reenforcing into the studs for more demanding uses such as floor joists. (1237,1270,1380)

Wood chemistry and fiber products

762. Wood is sometimes considered a vast new source of chemicals. The two major technical deterrents to the effective utilization of lignocellulosic residues for chemical, enyzmatic, or microbial conversion processes are cellulose crystallinity and the presence of lignin. Lignin restricts enzymatic and microbial access to the cellulose. Crystallinity restricts the rate of all three modes of attack on cellulose. Practical pretreatments which can open up the lignin-carbohydrate complex and can alter the fine structure of cellulose are needed. The many physical and chemical pretreatments investigated over the years are described and critically evaluated. (1331)

763. The potential role of wood as a material base for fuels and chemicals has been reviewed. It is proposed that wood residues at forest industry mills now offer several advantages as fuels for direct burning. Wood should be used on a structural material when possible. Incineration, landfill, and wood-derived industrial chemicals seem less advantageous than direct fuel (residues) and structural applications. (1315)

764. High prices of animal feeds and predicted world population growth make it necessary to search for methods to develop new sources of protein. Forest industry residues, urban wood residues, and municipal residues have been evaluated as potential sources for the production of protein by using them as animal feeds. The lignin must be removed from wood (as in pulp mill and paper residues) before the carbohydrate fraction of the wood can be effectively utilized as an animal feed. The economic, environmental, and technical considerations in wood-for-animal-feed have been summarized and will aid in assessing the feasibility of various advanced systems to use residues in protein production. (1330)

765. The utilization of wood residues for pulpwood sometimes requires the storage of unbarked (roughwood chips) which may deteriorate at a faster rate than debarked chips. Chips from unbarked and debarked red alder logs were stored for 6 months in simulators of chip piles. For both types of chips, essentially the same large losses in wood substance, pulp yield and pulp strength were observed. However, both types of chips can be effectively preserved over the same storage time by the use of a preservative. (1339)

766. More than one fourth of the pulpwood consumed by the paper industry is derived from wood wastes in the form of chips from lumber and plywood mills. During outside storage, chips deteriorate resulting in serious losses in wood fiber and chemical (tall oil) by-products. A screening of potential preservative treatments has shown several chemical combinations to be effective in significantly reducing losses of fiber and tall oil by-products. The reduction in tall oil losses alone can recover the cost of the preservative treatment. (1337,1338,1340)

767. With present papermaking processes, the lower quality high-yield and hardwood pulps often cannot be utilized for paper products where high strength and stiffness are required. Insufficient interfiber bonding results in a low-strength paper. A new drying system substantially increases interfiber bonding in these papers by restraining fiber movements in the thickness direction during drying. The resulting paper has greatly improved performance properties that permit it to be used where high strengths are required such as linerboard for boxes. The process greatly improves the potential for utilization of hardwoods. (1335)

768. Corrugated boxes often fail because the paper components are susceptible to stresses which cause adjacent layers of fibers to separate. An improved test procedure is now available to evaluate this mode of failure. The test method was tested and applied to fiberboard and hardboard specimens. This test procedure facilitates new improvements in the important compressive strength property of fiber boxes. (1316)

769. With the gradual depletion of many common construction materials, renewable wood and paper materials will assume a more important role in the future. On a weight basis, papers can surpass the stiffness and strength of wood if fibers are highly oriented, or aligned. Basic data on fiber orientation techniques are now available that can lead to wider use and substitution of stronger paper products in construction applications. (1341)

770. Strength properties of corrugated containers made from wood pulp derived from roughwood (wood chips with bark included) have been unknown. Tests on corrugated containers prepared from Douglas-fir roughwood have demonstrated that the strength properties of the container and its component linerboard were comparable to conventional commercial products, except for compressive strength which was significantly lower. Roughwood can be used to make container linerboard. Using roughwood for manufacturing corrugated boxes can effectively extend our wood resources by substituting for higher quality pulpwood. (1322,1323)

771. Corrugated fiberboard containers are of fundamental importance to commerce and are a major paper product on a volume basis. By optimizing material (paper) design properties through the use of a new idealized, more comprehensive container model, the strength of containers can be increased without utilizing additional fiber. (1327)

772. Corrugated fiberboard containers are the largest single category of paper products going into recovery and recycling processes. The effect of repeated recycling of container fiberboard has not been known. The first recycling reduces strength properties of a subsequent container up to 35 percent (with containers made from 100 percent recycled fiber). Subsequent recyclings have a minor effect. (1326)

773. Solid waste disposal is a serious problem for many municipalities. Recovering and utilizing more waste paper could reduce the solid waste problem. Recycled newspapers can be a potential source of fiber for corrugating medium. Blending 35 percent newspaper with mixed hardwood pulp and adding 2-1/2 percent starch resulted in a corrugating medium (for box manufacture) that was approximately equal in strength with a commercial corrugating medium. The medium showed satisfactory performance. This information provides municipalities with another means of utilizing some of their solid waste and the corrugating medium industry an additional fiber source. (1328)

774. By-products of the kraft pulping process have become the dominant source of naval stores (chemicals derived from the pine tree). Naval stores chemicals can serve as substitutes for petroleum products in many applications. A comprehensive review of the potential of naval stores chemicals is newly published. Potential new sources are examined, particularly the promising area of chemically induced oleoresin production in pine. The herbicides that induce heavy oleoresin formation in southern pine do not induce it in eastern hemlock to levels with commercial potential. (1324,1343,1344)

775. The neutrals fraction comprises 5-10 percent of the chemicals found in southern pine tall oil and represents an unused raw material. Little was known about their composition. A quantitative analysis identified over 80 compounds including all those present at the 0.1 percent level or better. Sterols and diterpenes predominate. Basic information on neutrals has been needed for more efficient processing of tall oil and the characterization of the neutrals could lead to new commercial products. (1319)

776. Chemically induced resin formation (lightering) in pine pulpwood trees before harvesting increases pine resin content several fold, but could have adverse effects on pulping procedures and pulp properties. Now it is known that artificially lightered wood can be pulped without difficulty and without loss in yield or quality of pulp. There is no significant change in the relative composition of the components in the resin (resin acid, turpentine, and fatty acid fractions). If artificial lightering becomes a widespread practice, the increased yield in pulp byproduct chemicals may significantly augment our petrochemical resources. (1329,1345)

777. Though high volumes of timber are available in the tropics, harvest is usually selective. Traditionally tropical forests have been skimmed of valuable species (high-grading). Greater emphasis on pulp and veneer processing that is tolerant to a variety of species is needed to permit a more complete harvest and utilization of existing trees. Correlations between wood density and tropical climatic life-zones suggest that woods with similar processing characteristics can also be correlated with climatic zones. Mixed stands can then be cut within a climatic zone and processed together. This system, along with processes tolerant to many species for the production of pulp, panel material, and/or structural timber, can help avoid high-grading and other silvicultural problems faced by managers of tropical forests. (1317)

778. The advent of whole-tree chipping has made it necessary to examine tree branches for properties that affect pulp yield and quality. Pine tree branches contain 21 to 33 percent bark; stems contain 10 to 13 percent. As branch size decreases, branchwood and branchbark specific gravity decreases and bark percentage increases. The strong and weak fiber characteristics of branch material have been quantified which makes it practical for the paper industry to predict the impact of total-tree pulping on fiber and paper quality. (1333)

779. No information is available on seasonal variation in weight of short-rotation (4 to 6 years) sycamore under coppice management. Seasonal variations may occur because of tissue maturation and the variations could affect pulp yields and pulp properties. The average dry matter content per cubic foot of 4-year old coppice sycamore increased 8.7 percent or 2.1 lb./ft^3 during the summer, remained constant during fall and winter, and decreased 3.8 percent the following spring. If the increase is caused by an increased amount of cellulosic wall material being laid down, a harvest cut later in the summer season would take advantage of the increased cellulose. (1318)

780. Among the serious waste disposal problems facing the U.S., disposal of municipal sewage sludge and wood processing residues are among the most troublesome. These wastes often coexist in the same communities and both can be beneficial for agricultural lands. One of the barriers to recycling sewage sludge as a fertilizer is that in large volume land applications, too much nitrogen may be released into the soil, surface runoff, or ground water. Wood and bark, on the other hand, when applied to land, tend to rob the soil of nitrogen as they decompose. By mixing sludge and wood wastes, it is possible to control the amount and rate in which nitrogen is released to the soil and plants. Wheat growth can be enhanced by fertilizing with sludge-wood-bark mixtures, turning the pollution and economic problems associated with sewage sludge and wood waste disposal into an asset. (1334)

Wood engineering

781. In some engineered applications (microwave drying), wood is subjected to varying electric fields. Data on the interaction of wood with such fields (dielectric properties) are valuable. A newly issued report catalogues these data over relatively wide ranges of important variables for design purposes, and shows the data to be consistent with a physically plausible theoretical model of wood. The data show an unexpectedly large positive interaction of frequency and moisture content, with extremely large values of dielectric constant for moist wood at low frequencies. This data is of value to manufacturers considering the use of wood as electrical insulators. (1358)

782. Underutilized eastern hardwoods represent a potential resource for meeting future wood fiber demands. A compendium of information on the mechanical properties of 23 hardwood species provides a key to their extended utilization. A method is also described for utilizing hardwoods in structural applications (beams and rafters) where building codes (and other regulatory authority) do not prohibit their use. (1346)

783. In the design of wood structures, design parameters are established on the basis of the analysis of component units (rafters, walls) rather than on a total integrated structure. By racking a complete wood-frame structure, the strength of the total structure was determined. Conventional wood framing provides excellent strength. Under severe stresses, floor-to-wall connections failed first. Other tests show that moisture gradients in roof joists can cause bowing and subsequent separation of interior ceiling from wall. Such weaknesses can easily be rectified with minor design changes. (1388,1389)

784. Timber bridges are widely used in rural areas and on Forest Service roads. They are durable, economically attractive, and can be erected with a minimum of skilled labor and equipment. The newly developed glued-laminated bridge deck provides excellent structural performance, and promises to extend the service life of the bridge by protecting the superstructure. An efficient construction procedure is presented, and suggestions made to avoid common pitfalls. (1387)

785. Single and multi-family wood-frame dwellings which are outmoded or in a deteriorating condition exist in communities throughout the country. Many of these homes could be rehabilitated at a lower cost than new construction and with much less material than a new home. To promote the twofold advantage of lower cost houses and conservation of our natural resources, a guide was developed for appraising the suitability of woodframe dwellings and to serve as a guide for rehabilitation. It includes information on examining a house to determine its suitability for rehabilitation, the consideration of esthetic values, planning for improvements to be made, and details for accomplishing the rehabilitation. It should be useful to homeowners, lending institutions, and contractors. (1382,1383)

786. The degree to which sound is transmitted through partitions and throughout a structure is an important factor in structural adequacy. Wood-frame and wood-based panels are good sound insulators. Correlations between field tests and lab tests of the insulation value of wall components have been described. Sandwich construction type panels alone do not give adequate sound insulation. An auxiliary wall added to a conventional stud and gypsum board wall can provide adequate sound insulation in the resulting partition. These factors are important to architects, loan agencies, builders, code agencies, and others interested in maintaining privacy in multifamily dwellings. (1360,1361,1362,-1363)

787. There are no standard test methods available for evaluating the impact behavior of plywood and particleboard sheathing alone. The feasibility of testing a small panel over a single span with the joists fully supported and the effect of panel size and edge condition were investigated. A reliable test method was developed for evaluating the sheathing. This makes possible realistic evaluations of new sheathing materials such as particleboard panels made from ordinary tree harvesting wastes or hardwood plywoods. Results will be useful to code and standards groups, sheathing manufacturers, and other researchers in the structures field. (1385)

788. Shipping pallets consume more than 14 percent of the Nation's annual timber supply. Longer-lasting pallets can aid in conserving lumber. Pallets last longer when forklift trucks are equipped with specially fabricated "impact panels" that distribute the stresses on pallet deckboards when they are rammed by the forklift during pick-up. The nails used in pallet manufacture are largely imported. The use of available, sufficiently effective U.S.-made staples could reduce dependence of domestic pallet producers on foreign nail sources. Using 2 1/2-inch-long plastic-coated staples, pallets made with about one-third more staples yield equivalent performance to nailed pallets and are cost-equivalent. This information is helpful to all pallet producers and users seeking an alternate supply of pallet fasteners. (1365,1384)

789. Shipping pallet decks are ordinarily made of solid wood boards. Boards could be replaced in some cases by decks made of recycled fiber, if performance is found to be satisfactory. The performances of pallets made with five experimental medium-density hardboard decks were compared with performances of similar pallets made with decks of commercial particleboard, plywood, and knife-cut veneer. The results showed that equivalent performance is produced by pallet decks of thicker medium-density hardboard, and this capability could help to reduce the expected shortage of pallet component material. (1366)

790. New engineering data on difficult-to-evaluate structural components has been developed. Particleboard specimens were evaluated at different rates of loading in bending, tension, and shear. This data will be used to develop reliable design criteria for particleboard. The properties of hardboard-webbed I-beams were experimentally evaluated and compared to known engineering theories. Beam behavior under short-term loading can be reasonably well predicted from fundamental engineering theory. (1371,1386)

791. Wood fiber from urban residues such as wastepapers, discarded pallets, dismantled railroad cars, and diseased elm trees has potential use in wood-base particleboard panel products such as medium-density board materials for furniture core stock. Dry-formed, medium-density hardboards have been made from various combinations of these residues. Most of the properties of the boards are as good as those required for mat-formed particleboard, but they were not as good as properties of commercial dry-formed, hardboards. This information will be useful for potential producers and consumers of these materials and to municipalities considering the use of wood fiber waste for making panel products. (1367)

792. Fire safety regulatory agencies recognize certain inadequacies in the methods and procedures used for defining "noncombustible" materials. A potentially improved method based on "rate of heat release" of a material has been developed. Information on rate of heat release for typical wood-base building materials subjected to fire exposure (certain plywoods, hardboard, lumber products, insulation board and particleboard) has been developed. Results are important to regulatory officials, researchers, and material producers. (1348)

793. A knowledge of fire endurance characteristics of structural sandwich panels is necessary if acceptance criteria are to be established for use in single family and other housing construction. Tests conducted on both sandwich panels and wood-frame wall panels provide performance data on panels with and without chemicals to extend fire resistance times. Treating wood building materials with sodium dichromate will reduce the amount of smoke generated under certain flaming and non-flaming conditions. (1349,1351)

794. Automatic lumber grading machines help ensure that the highest potential use is made of the timber harvested. A prototype stress-wave lumber grading machine was developed. The control and computing function for this machine is designed around a micro-processor system. Successful use of this microprocessor system will encourage similar versatile and reliable control systems in the wood products industry. (1350,1369)

795. Due to current interest in history of the Nation, a description is provided of procedures used in building a plantation house that was constructed in 1796 in central Louisiana. Reliance was almost exclusively on local materials. Though French tradition and culture predominated in Louisiana, carpenters' tools of English design seem to have been favored. (1379)

796. The ends of heavy timber beams exposed to the weather are subjected to large changes in moisture content that cause checking, degradation of finishes, and the danger of decay. Finishes, flashings, and other protective covers may be used to minimize weathering effects, and recommendations based upon observations of past designs and current exposure experiments are offered. These recommendations are of value to architects and builders. (1375)

797. The shortage of high-quality hardwood timber, coupled with general price increase, has resulted in the need for a means of accurately estimating quality in the standing tree. A tree grading system that is directly related to predicted lumber grade yields has been developed. Application of the system requires the measurement of diameter and merchantable height, and the estimation of defects. Lumber grade yields are available by tree grade and size for the following species: yellow and paper birch, red and sugar maple, black cherry, yellow-poplar, basswood, and northern red, black, white, and chestnut oak. The lumber grade yields enable timber buyers and sellers to estimate the value of graded trees. The grading system may also serve as

the basis for stratifying tree quality during a forest inventory. (1356)

Prevention and Control of Wood-destroying Organisms

798. Immediate utilization of loblolly pine logs infested with southern pine beetles is nearly impossible with today's processing techniques. In Maryland, the economic feasibility of water spray storage was tested as a means of saving such logs for use as piling and sawlogs, 1 to 2 years after their beetle infestations had passed. Results after 15 months of storage indicate that tree-length logs can be stored with little or no net cost to yard operators. Spray-storage of piling-class logs was more profitable than storage of sawlogs due to a slight benefit from increased penetration of creosote into the heartwood. Forest managers and timber users can now increase the use of beetle-infested logs through better storage techniques. (523)

799. Laboratory studies with subterranean termites require a uniform diet of known constituents upon which the termites can survive and reproduce as well as on wood. A diet that contained 34.06 percent alpha cellulose, 65.87 percent water, 0.06 percent sterol, and 0.01 percent methyl-p-hydroxybenzoate met these requirements. For the sterol ingredient, both B-sitosterol and ergosterol were superior to cholesterol. This diet will (a) eliminate the use of a wood diet with its widely varying chemical composition, (b) allow more accurate measurement of experimental variables, and (c) serve to accelerate control-related research on subterranean termites. (527)

800. Better knowledge of natural toxic or repellent substances in wood may become the basis for the development of new methods for termite control. The survival of the Formosan subterranean termite was studied on sawdusts, solvent extracted sawdusts, and absorbent paper pads treated with extracts prepared from 23 species of resistant tropical hardwoods. Termites could not survive on absorbent paper pads treated with extracts from 14 woods. These results will serve as the basis for isolating termiticidal substances from these 14 woods and determine their utility as termite repellents or toxicants. (524)

801. Many houses are constructed with built-in errors that will predispose them to damage by wood-decay fungi, termites, or other wood-destroying insects. Fifteen percent of all owners of houses built after 1969 in one county bordering the Gulf Coast reported wood damage in their homes due to these agents. Most of this damage could easily have been prevented. A method of inspection that focuses attention on quality control within samples of houses, rather than an inspection program that requires a superficial examination of all houses under construction, is proposed for consideration by members of the Southern Building Code Congress. (525)

802. The toxic chemicals added to wood in conventional preservative treatments are a source of environmental concern. By modifying the chemical structure of wood with non-toxic alkylene oxide derivatives, it becomes resistant to fungal attack and less likely to swell, shrink, or warp. A model is presented as a guide for the selection of conditions and chemicals for effective treatments. This treated material is suitable for a variety of products such as flooring, window units, and tool handles. (1300,1301)

803. Except for the naturally durable wood species such as redwood and black locust, the service life of wooden pilings, poles, and fence posts is often limited by decay associated with moist wood conditions. Preservative treatments can reduce or prevent decay, greatly extend service life, and result in an economic market for many small trees and thinnings as posts. A broad program of in-place, long-term testing of potential preservatives and preservative systems used on various species is demonstrating the degree of effectiveness of preservative treatments and expected service life of treated posts. Tests sites are located in Mississippi, Alabama, Louisiana, Florida, Georgia, Tennessee, Maryland, New York, Wisconsin, South Dakota, Illinois, Missouri, Nebraska, Colorado, Montana, Hawaii, and Panama. (1252,1253,1254,1275)

804. Knowledge of physiological mechanisms which enable fungi to decompose wood is important if we want to prevent decay or to utilize these organisms in industrial processes. A physiological explanation of how brown-rot fungi rot wood suggests that the peroxide-iron system of the fungi might be used to treat cellulosic material for industrial use. Phenolic or iron-chelating compounds which may be produced by nondecaying isolates of decaying species may offer possibilities as a prepulping treatment. (1269)

MARKETING UNDER-USED SPECIES AND RESIDUES

805. To quantify logging residues, a reliable and efficient sampling method was needed. The line intersect method was tested in Appalachian hardwoods and found to provide accurate estimates of volume in cubic feet per acre. A computer program was prepared to process large amounts of data in a short time. Thus, land managers can transform field measurements into useful summaries with minimum effort, and can adequately estimate volumes of hardwood logging residue using the highly efficient line intersect method. (1159,1160,1162)

806. To anticipate logging residue conditions that are likely to exist after a selection cut, the forester needs a means of predicting residue amounts from individual sawtimber-sized trees. An equation was developed using data from 36 mixed oaks in southwestern Virginia. Dbh, bole length, and sawlog height are used to predict gross volume in cubic feet for each tree marked for cutting. The sum of individual tree volumes can then be converted to a per-acre or stand basis. The forester now has one more planning aid that can be used to evaluate alternatives before harvesting and utilization decisions are actually made. (1161)

807. Railroads are spending millions of dollars annually to dispose of old ties that might otherwise be converted into useful industrial fuel. Studies of crosstie weights revealed that the average old crosstie weighs about 190 pounds. On a national basis, about 2 million tons of old crossties are available for use each year. Studies of fuel values revealed that 1 ton of old ties has the equivalent heat of about 100 gallons of No. 2 fuel oil or 1/2-ton of bituminous coal. Nationally, the use of old crossties could replace the annual consumption of 4 1/2 million barrels of imported oil. Income from the sale of these old ties could be channeled into the purchase of new ties to improve deteriorated roadbeds. Thus, the lagging forest economy would be enhanced by this marketing venture. (1153,1154)

808. Markets are needed for low-grade Appalachian hardwood logs. An evaluation of plywood made from combinations of

Appalachian species found that 16 different species combinations will meet PS 1-66 standard. Because of the species mixture in Appalachian forests, the most likely combinations for commercial production would consist of red oak, hickory, and hard maple outerplies with yellow-poplar, soft maple, and black gum innerplies. Development of a hardwood plywood industry in the Appalachians would expand markets for low-grade timber and help extend the Nation's softwood timber resource. (1155)

809. Hardwood bark is an effective amendment for improving the physical structure of soils used in horticultural containers. Different shredding processes may influence the availability of bark-absorbed water. This study determined the effectiveness of bark as a water reservoir for plants. The results will be useful in further research to develop improved horticultural growing media. (1163)

810. Sawmill operators and other primary wood processors are in need of commercial uses and markets for large quantities of bark. The highway market for mulch for revegetating disturbed soils offers a large potential market for this material. All species of bark are suitable for revegetative mulching, and the fibrous and bulky nature of bark make it unnecessary to use asphalt or other binders to hold it in place. This study describes the requirements for bark mulch for both seeding and planting, the estimated market potential for 26 eastern States, and provides bark producers with guidelines for entering the market. (1158)

811. In the United States, sawdust has been burned for fuel mostly in individual boilers, special home-heating furnaces, and as reconstituted fireplace logs. A report describes how to construct and use a practical, low-cost sawdust stove for heating cabins or workshop areas. Such stoves, in common use in other parts of the world, can be used to heat a room 20 feet square for 6-10 hours without tending. (1164)

812. Because of rapid inflation in fossil fuel prices and severe problems in nuclear-power programs, wood has been suggested as a primary fuel for steam-electric plants. The estimated total 1970 volume of unused lumber and plywood mill residues and logging residues (in pieces above 4 inches in diameter) would have been sufficient to meet about 10 percent of the annual fuel requirements for U.S. steam-electric plants. Costs of collecting, transporting, and preprocessing logging residues probably were too high for such materials to be competitive with coal in most regions, even at average 1974 coal prices. Use of waste bark and wood as fuel by forest products plants, however, appears highly advantageous and will limit the availability of mill residues to commercial steam-electric plants . (1156,1157)

813. Potential market outlets for forest residues include use for particleboard, historically the most rapidly growing sector of the wood products industry. Resource, investment, market, and locational factors are likely to influence further development of the particleboard industry in the northern Rocky Mountain area. Results indicate that expansion will be located close to mill wastes until this source is exhausted. As mill wastes become scarce, plants will be designed to make use of forest residues. The report provides a basis for evaluating probable utilization trends in particleboard, and a broad economic analysis from which more specific plant feasibility analyses can be made. (1166,1167)

SUPPLY, DEMAND, AND PRICE ANALYSIS

814. Although expenditures for U.S. highway construction increased about 2 1/2 times from 1954 to 1972, the use of wood products in this industry remained nearly constant during the period. Even so, annual use ranged from 400- to 500-million board feet. This level of use is likely to continue, but expected shortages and higher costs of materials from nonrenewable resources may make wood more attractive and competitive for highway construction use. This study provides details of types of wood used, and other information useful to wood products suppliers interested in the market. (1173)

815. Indiana's business community needs information about the black walnut timber resource situation. A new report describes the resource, its economic importance, and long-run outlook for increasing supplies of quality timber for benefit of persons interested in growing black walnut in Indiana. (1184)

816. Recent unfavorable economic conditions and changing long-run demographic factors have called into question the realism of past projections of long-run housing demand. This study examines the effects of demographic change and alternative economic policies on long-run housing requirements. New housing projections are provided for alternative levels of long-run economic growth. These should prove helpful in examining the current long-run outlook for housing construction and forest products requirements. (1174)

817. The mobile home industry is a major user of forest products. Information on industry consumption is essential to accurate analyses of total demand for timber products. Georgia leads the Nation in production of mobile homes. The average mobile home built in Georgia in 1973 used 1,982 bd. ft. of lumber, 1,009 sq. ft. of hardwood plywood (3/8-inch basis), 812 sq. ft. particleboard (3/4-inch basis), 255 sq. ft. of softwood plywood (3/8-inch basis), and only 33 sq. ft. of hardboard (1/8-inch basis). The increased use of lumber—334 more bd. ft. than in 1970—was attributed mostly to increased strength requirements in the State's construction code. The construction of larger single-wide units and more double-wide units was an important factor in the use of large quantities of hardwood plywood and particleboard. With the emphasis on larger mobile home units, the mobile home industry provides most of the new low cost housing for Georgia while using large quantities of lumber, hardwood plywood, and particleboard. (1169)

818. The insulation board, hardboard, and particleboard industries have greatly increased production with consequent larger consumption of wood raw materials. Medium-density fiberboard (MDF), whose classification as a hardboard or separate product is currently under much discussion, represents a blend of processes and raw materials used by the particleboard and hardboard industries. By 1980, production of MDF board is estimated to be 1 billion sq. ft. (3/4-inch basis). An even newer product is thin particleboard. It was estimated that 147 million sq. ft. (3/4-inch basis) of this board was manufactured in 1973. In the long run, the woodbase fiber and particle panel industries will have a competitive advantage over many other wood products industries because of their ability to use underutilized raw materials such as low quality roundwood and wood residue of both hardwood and softwood species. (1170)

819. One requirement for long-range timber forecasts is to ascertain the probable impact of technological change on the consumption of stumpage. This paper proposes a measure of technological change for the lumber and wood-products industry. The findings indicate that technology was advancing at an average rate of 1.75 percent per year between 1949 and 1970. Such findings improve our ability to predict the consumption of stumpage and to formulate policies relative to our forest resources. (1177)

820. A recent publication describes the essentials of futures trading with respect to lumber, presents a few examples of how the industry might benefit from this activity, and explores the trading potential of different segments of the industry. Results show that this marketing tool can help the industry to forward-price, minimize its inventory risk, earn a carrying charge on its inventory, and enlarge its inventory financing. The strongest trading potential exists among large firms producing, distributing, and using western lumber items. Southern pine lumber producers, distributors, and users do not have as strong an incentive for hedging as their western counterparts. (1178)

821. Public policy choices in many program areas can be improved with information about prospective and feasible levels of aggregate timber supply from the Pacific Northwest. A recent study shows that significant declines in timber harvest will occur over the next 15–30 years under present harvest scheduling policies even with a higher level of management than is currently being applied. While many reforestation opportunities exist, they will not yield significant harvests within the next 15–30 years. (1172)

822. An understanding of the trade-offs between the log export and domestic timber processing industries is necessary to weigh alternative export control policies. Direct employment per thousand board feet of logs processed is higher in domestic lumber and veneer and plywood industries than in the log export industry. However, relative product values and indirect effects of domestic and export markets vary over time. Success of policies to maximize trade-offs between markets is not certain because responses of industry members to changes in policies are uncertain. (1168)

823. Current information on forest industry activities is of interest and use to timber managers, processors and users of forest products. Quarterly marketing reports on forest industries of the Northwest present up-to-date information on production, prices, employment, trade, volume and value of stumpage sold by public agencies, and other related items for Washington, Oregon, northern California and Alaska. (1179,1180,1181,1182,1183)

824. An understanding of how national economic forces affect local economies is essential for planning at the local level. Oregon's forest products industries have been squeezed between rising timber prices and declining demands for processed products. Cycles in forest products prices and employment are keyed to domestic rather than export markets. (1176)

825. After sawlogs, veneer logs, and pulpwood, wood poles are the most important end-use for industrial roundwood. Although no specific projections have been made, expansion of demands for electric and communication facilities, growing needs for utility pole replacements, and rising use of poles in construction, should result in increases in wood pole demand in the years ahead. An analysis of regional softwood timber inventories and pole production and preservative treatment indicates that supplies of timber suitable for poles are adequate for the foreseeable future. (1171)

826. Demand for most timber products dropped sharply in 1974 and early 1975 in response to declines in activity in the principal end-use markets. However, based on trends in the fall of 1975 and an analysis of the factors expected to affect these markets in 1976, the outlook for most products is for renewed growth in production and consumption. International trade should also increase in 1976 as the economies of both the United States and its major overseas customers for wood products improve. With increased demand and consumption, prices for timber and timber products can also be expected to rise. (1175,1185)

IMPROVED MARKETING SYSTEMS

827. Logging operators need to forecast harvesting costs for proposed timber sales if they expect to maintain a profitable business. For each logging job, they should evaluate the mix of men and machines and predict the effects on costs when changes in the system are proposed. A computer program was developed to simulate the complete harvesting sequence from standing tree to mill. The simulator is designed for Appalachian conditions, but can easily be modified for use in any region. With it, the logging manager can simulate alternative harvesting systems and examine any number of changes without incurring large capital expenses. (1202)

828. Some timber in the Appalachian Region does not have enough volume or value to warrant construction of good truck roads. However, our studies showed that off-road log haulers called forwarders could operate successfully in mountain terrain even with adverse weather and road conditions. Forwarders enable loggers to harvest timber considered unavailable because of location or cost of extraction. (1208)

829. Tandem-axle log trucks weighed in West Virginia carried so much load weight on the rear axles that maximum legal payloads could not be hauled. A logging truck design guide was developed to show loggers how to determine the correct truck wheelbase and body configuration. By using this guide, loggers can maximize truck payloads without exceeding either the manufacturer's specified axle weight capacities or the legal axle weight limits. With optimum load weight distribution, the legal payloads of the trucks sampled could be increased an average of 6,000 pounds. (1191,1192)

830. The practice of scaling hardwood sawlogs by weight has not yet become widely accepted. Millowners continue to stick scale because existing weight scaling systems are hard to start, troublesome to check, and difficult to adjust. The adjusting factor method of weight scaling eliminates these difficulties because weight per board foot conversion factors are constantly modified to cover fluctuations in sawlog characteristics. From a test of 500 truckloads of mixed hardwood logs, volume differences between adjusted weight scaling versus stick scaling were less than 3.5 percent. Adoption of the adjusting factor method could help improve working relationships between log producers and buyers through a mutually acceptable scaling practice. (1186)

831. Segments of the forest products industry have shifted from volume to weight as a base for marketing transactions. Yet

there has been no published data showing the relationship between weight and gross cubic volume for rough forest products. Data from about 4,500 Appalachian hardwood logs have been analyzed to show weight/volume ratios for prevalent species. Tables show the ratio between sawlog weight including bark and cubic sawlog volume both with and without bark. Lumbermen can use these values to determine quantities of marketable by-products such as chips, bark, and sawdust in relation to sawed lumber volumes specified by weight scaling. Researchers should find the ratios a helpful tool in developing new weight/volume mensuration techniques. (1209)

832. Air drying is too slow and erratic to permit hardwood lumber producers to meet marketing schedules and changes in market demand; it also frequently results in excessive lumber degrade losses. To help alleviate these problems, we developed a commercial-scale low temperature dryer for drying hardwoods to the "air dry" condition. The dryer utilizes solar heat to dry hardwood lumber in 1/3 to 1/4 the time and with about 1/3 the degrade losses experienced in air drying. (1195)

833. In order to increase hardwoods' share of the $1 billion office furniture market, it is necessary to know what factors influence the selection of this type of furniture. It was found that quality, appearance, and purchase price have the most important influence on the purchase decision. Intended use and appearance were the key factors in the purchase of wooden furniture. With this knowledge, manufacturers of wooden office furniture can adjust their marketing strategies to improve the competitive position of wood. (1187)

834. The tremendous increase in pallet usage in recent years has resulted in the need to establish a pallet repair and salvage industry. Basic information on types of damage, severity, and location were determined so that pallet repair standards could be developed. With proper repair standards and efficient equipment, it was found that 92 percent of the damaged pallets could be economically repaired and reused. Establishment of an efficient pallet repair and salvage industry could greatly extend the use of our hardwood resources. (1196)

835. Softwoods and low density hardwoods have long been considered inferior for production of reusable wooden pallets. Research has shown that properly designed and constructed pallets of softwood and low density hardwood (aspen) lumber will perform as well as or better than oak pallets. Pallet production is expected to double in the next 10 years. Use of the light wood species could greatly increase the supply of raw materials for this industry. (1188,1207)

836. The cost of injury-causing accidents in the logging and sawmill industries and its impact on prices and profits has not been fully shown. A study in Central Appalachia showed these costs ranged between $9 and $11 million annually—not including the 40 to 50 percent of injured workers' wages that were unrecoverable. Cost estimates of injuries are a necessary step in persuading foremen and managers to insist on safe practices and accident prevention programs and equipment. (1204)

837. Members of the Christmas tree industry have limited access to published information to help solve their production and marketing problems. Lack of such information perpetuates inefficiencies in individual operations and within the industry as a whole. A bibliography was recently published and now provides a means of quickly locating the most recent information available. Use of such information will assist Christmas tree producers, wholesalers, and retailers in making realistic decisions on production and marketing practices, and place the rurally-oriented Christmas tree industry on a stronger economic base. (1203)

838. Efficient, low cost methods of sap production are needed by the pure maple syrup industry. This study compared the traditional bucket collection system with plastic tubing and vacuum pumping and found the plastic tubing-vacuum pumping method cost less. Efficient operation, control of production costs, and acceptable profit margins are keys to successful maple syrup operations. (1201)

839. An expanding pulp and paper industry in Illinois could affect all forestry interests in the State. Current data on pulpwood marketing are needed. A study of Illinois mills shows the number and types of mills have remained stable, but pulpwood requirements have increased. Use of residues is increasing and the number of roundwood producers is declining. Price increases and competition for wood are important problems. This information is useful to other wood-using industries, forest managers, and planners in depressed areas with abundant wood resources. (1190)

840. Production and cost analyses of logging systems are needed to develop ideal timber management methods and efficient utilization systems. Complex logging systems used today are beyond the analytical ability of simple work study methods. This study describes a model of a field chipping and trucking system using computer simulation which allows a user to design and operate systems to fit unique timber and market conditions. (1193,1194)

841. The Jones Act gives British Columbia producers a transportation cost advantage over U.S. West Coast producers, and has been cited as the primary reason for the increase in lumber shipments from British Columbia to the U.S. East Coast at the expense of Pacific Northwest shipments. In the context of the total competitive environment between the two areas, however, other factors—especially stumpage price differences—may override this advantage. If exempted from the Jones Act, Pacific Northwest softwood producers would have to prepare for assembly of cargo and development of East Coast markets to take full advantage of lower-cost foreign flag vessels. Evaluation of the impact of the Jones Act should be within the context of the Act's objectives, the need for waterborne as opposed to other transportation modes, and the market forces which determine competition with British Columbia. (1189)

842. As crucial as its role is, the timber harvesting business is probably the least understood segment of the wood-using industry. An extensive survey of commercial logging in the Northeastern United States was conducted in 1974. Results provide a profile of the region's loggers and indicate practical limits to commercial logging. We found, for example, that no logging operations cut less than 3 acres or remove less than 2000 cubic feet of timber volume. Very few loggers skid more than 3/4 mile or main haul more than 100 miles to a purchase point. Results are being analyzed to discover key determinants of successful logging. (1199,1200)

843. A viable wood products industry requires that sources of materials and the identity of users be known. In a recently compiled directory, all forest products industry firms in Idaho that operated in 1973 to 1974 are identified by alphabetical listing, by

county, by product produced, and by species utilized to manufacture specified products. The directory is intended to help decision makers determine who might be affected by alternative policies, to help buyers determine who might be producing desired products, and to help industry people to indentify forms with similar interests. (1197)

844. Residential construction is the major market for softwood lumber, and most lumber used in housing is in floor and wall framing. In assessing demand for lumber, it is important to know what effect changes in material and labor costs will have on the competitive position of wood and metal for framing. This study shows the comparative in-place cost of wood and aluminum framing as material and labor costs change over time. (1210)

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